REPORT

OF THE

MINISTER OF EDUCATION

ON THE SUBJECT OF

TECHNICAL EDUCATION.

Printed by Order of the Legislative Assembly.

Toronto:
PRINTED BY WARWICK & SONS, 68 AND 70 FRONT STREET WEST.
1889.

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STEVENS' INSTITUTE OF TECHNOLOGY (HOBOKEN, NEW JERSEY):

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APPENDIX:

REPORT

OF THE

MINISTER OF EDUCATION

ON THE SUBJECT OF

TECHNICAL EDUCATION,

BASED UPON A VISIT TO CORNELL UNIVERSITY; LEHIGH UNIVERSITY; COLUMBIA COLLEGE; THE STEVENS INSTITUTE, HOBOKEN, AND THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

To the Honorable SIR ALEXANDER CAMPBELL, K.C.M.G.,
Lieutenant-Governor of the Province of Ontario.

MAY IT PLEASE YOUR HONOR:

I have the honor to submit herewith a report on the subject of technical education as found at Cornell University, New York; the School of Mines, New York City; the Stevens Institute, New Jersey; Lehigh University, Pennsylvania; and the Massachusetts Institute of Technology, Boston.

In company with Professor Galbraith of the School of Practical Science, I visited all these institutions in June last, in order to acquaint myself with the character and extent of the accommodation and equipment required, and the course of study found most valuable for technical purposes.

At all the places mentioned I found the most liberal provision made for the comfort of the students. Cornell University has already expended $185,000 on buildings, and at the time of my visit was engaged in erecting additional buildings at a cost of $140,000. Lehigh University has expended over $1,000,000 on buildings, almost exclusively for technical education. The Massachusetts Institute of Technology expended $700,000 for sites, buildings and furnishings, and the School of Mines $690,000 for similar purposes, including a museum.

As a rule all the institutions visited were built with very little regard to architectural effect. Not one of them would compare with the University of Toronto in external appearance, although they were all much superior in internal arrangements.

The equipment of the institutions varied according to the course of study pursued. At Cornell, the Stevens Institute and the Massachusetts Institute of Technology, in addition to the ordinary apparatus for physical and mathematical purposes, workshops were established, in which all the processes for manufacturing iron, from the smelting furnace to a finishing shop, were carried on. Iron lathes, planers and forges were provided for the students, and at certain hours during the day the School was turned into a large workshop. Carpentering, in all its variations, was also taught at the schools above named, and the proper use of the jack-plane and saw insisted upon as much as the demonstration of Euclid's Theorems. But apart from the mere workshop, the equipment of the five institutions visited was very liberal. Cornell heads the list with an expenditure of $141,500, then comes the Stevens Institute with an expenditure of $100,000, then the School of Mines $50,000, and the Massachusetts Institute with $45,000. It would be impossible for me to name in detail the various appliances in the large physical laboratories which I had the pleasure of visiting. Suffice it say, that they in some form or other illustrate every department of engineering. The attendance of students at the different institutes varied from 168 at the Stevens to 368 at the Massachusetts Institute.

The provision made for instruction is also very generous. Cornell University paid last year $32,750 to Professors and Instructors in the Technical Department alone; and also gave the students of this department access to the lectures in Chemistry, Physics and Mathematics at the University proper, from Professors receiving salaries amounting to $28,850.

The Professors and Instructors at the Massachusetts Institute, exclusive of the workshops, receive $27,600 in the way of salaries.

At the School of Mines, New York City, particular attention is paid to mining engineering and assaying. The various processes by which the ore is prepared for the market are studied and illustrated by appropriate machinery and other devices.

At this School also, the study of Chemistry, in its relation to the arts and manufactures, occupies a prominent place. The dyeing of textiles of all kinds is taken up practically in the laboratory by every student taking a course in applied Chemistry.

The greater portion of the matter contained in this report is taken from the calendars of the institutions referred to, with very little change, except in its arrangement.

I have the honor to be,

Your obedient servant,

GEO. W. ROSS,

Minister of Education.

CORNELL UNIVERSITY.

The Faculty.

Cornell University is situated at Ithaca, in New York State. The equipment for Technological purposes is of the most thorough character. The Science Faculty consists of nineteen professors and assistants, and twenty-four instructors, as follows:

Charles Kendall Adams, LL.D., President.

George Chapman Caldwell, B.S., Ph.D., Professor of Agricultural and Analytical Chemistry.

John Lewis Morris, A.M., C.E., Sibley Professor of Practical Mechanics and Machine Construction.

The Rev. Chas. Babcock, A.M., Professor of Architectnre.

James Edward Oliver, A.M., Professor of Mathematics.

Estevan Antonio Fuertes, C.E., M.A.S.C.E., Professor of Civil Engineering, and Dean of the Department of Civil Engineering.

Robert Henry Thurston, A.M., Doc. Eng., Director of Sibley College; Professor of Mechanical Engineering.

Edward Leaming Nichols, B.S., Ph.D., Professor of Physics.

Spencer Baird Newbury, E.M., Ph.D., Acting Professor of General, Organic and Applied Chemistry.

Lucien Augustus Wait, A.B., Associate Professor of Mathematics.

Edwin Chase Cleaves, B.S., Associate Professor of Freehand Drawing and Mechanical Drawing.

Charles Lee Crandall, C.E., Assistant Professor of Civil Engineering, in charge of Road Engineering and Geodesy.

Irving Porter Church, C.E., Assistant Professor of Civil Engineering, in charge of Applied Mechanics.

George William Jones, A.M,, Assistant Professor of Mathematics.

George Sylvanus Moler, A.B., B.M.E., Assistant Professor of Physics.

Charles Francis Osborne, Assistant Professor of Architecture.

Charles David Marx, C.E., Assistant Professor of Civil Engineering, in charge of the Graphics of Engineering.

Frank Harvey Bailey, Passed Assistant Engineer, U.S.N., Assistant Professor of Mechanical Engineering; Instructor in Marine Engineering.

Albert William Smith, M.M.E., Assistant Professor of Mechanical Engineering.

Frank Van Vleck, M.E.. Assistant Professor of Drawing.

James McMahon, A.B., Instructor of Mathematics.

Frank Howard Morgan, B.S., Instructor in Quantitative Analytical Chemistry.

Bolton Coit Brown, B.P., Instructor in Industrial Art and Drawing,

Arthur Stafford Hathaway, B.S., Instructor in Mathematics.

James Furman Kemp, A.B., E.M., Instructor in Geology and Mineralogy.

Eugene Henry Preswick, B.S., Instructor in Qualitative Analytical Chemistry.

Rufus Anderson, M.E., Instructor in Mechanical Engineering, and Foreman of the Machine Shop.

Herman Atkins McNeil, Instructor in Industrial Art.

Charles Benjamin Wing, C.E., Instructor in Civil Engineering.

William Ridgely Orndorff, A.B., Ph.D., Instructor in General and Organic Chemistry.

Louis Munroe Dennis, Ph.B., B.S., Instructor in Chemistry.
Duane Studley, B.S., Instructor in Mathematics.
Daniel Webster Gunner, C.E,, Instructor in Civil Engineering.
George Egbert Fisher, A.B., Instructor in Mathematics.
Julius Howard Pratt, jr., A.B., Ph.D., Instructor in Physics.
Arthur Henry Rowe, Instructor in Architecture.
Herman Klock Vedder, C.E., Instructor in Civil Engineering.
Frank Hovey Noyes, Instructor in Freehand Drawing.
James Wheat Granger, Instructor in Forging.
William Henry Wood, Instructor in Woodworking.
James Elijah Vanderhoef, Instructor in Moulding.
Fred. Clarkson Fowler, Mechanician, and Instructor in Physics.
Grant Adelbert Covell, M.E., Instructor in the Machine Shop.
George Pollay, Instructor in the Wood Shop.

Special Lecturers.

Besides the instruction regularly given by the resident officers of the University, a large number of lectures are delivered by non-resident lecturers on special subjects of importance. For this branch of instruction the services of eminent specialists are sought, and the number of lectures given by each lecturer varies according to the nature of the subject treated. In the year 1886-87 the lecturers were as follows:

Andrew Dickson White, LL.D., Lecturer on German History in the Nineteenth Century, *University Grounds.* Goldwin Smith. LL.D., L.H.D., Lecturer on English Constitutional History, *Toronto, Canada.* Frank B. Sanborn, A.M., Lecturer on Social Science, *Concord, Mass.* Rodolfo Lanciani, LL.D., Lecturer on Results of Recent Explorations in Rome, *Rome, Italy.* Charles Waldstein, Ph. D., Lecturer on Classical Archæology, *Cambridge, England.* The Hon. Seth Low, A.M., Lecturer on the Problems of Municipal Government in America, *Brooklyn, N.Y.* President George W. Atherton, LL.D., Lecturer on the Education of American Farmers, *State College, Pa.* President Edwin Willets, A.M., Lecturer on Land Tenure and the Limitations of American Agriculture, *Agricultural College, Lansing, Mich.* Woodrow Wilson, Ph.D., Lecturer on Methods of Administration, *Bryn Mawr, Pa.* Washington Gladden, D.D., LL.D., Lecturer on The Ethical Relations of Capital and Labor, *Columbus, O.* Frederick William Simons, M. S. Ph. D., Lecturer on Economic Geology, *University Avenue.* James Julius Chambers, Ph. B., Lecturer on Journalism, *New York City.* Lauren Briggs Arnold, Lecturer on Dairy Husbandry, *Rochester, N.Y.* Grove K. Gilbert, B.S., Lecturer on The Field Work of the U. S. Geological Survey, *Washington, D.C.* Charles Edward Emery, Ph.D., Lecturer on Steam Engineering, *New York City.* Henry Metcalfe, U.S.A., Lecturer on Manufactures and Engineering. Eckery Brinton Coxe, M.A., E.M., Lecturer on Mining Engineering, *Drifton, Pa.* John Wilmuth Hill, M.E., Lecturer on Steam for Water Supply, *Cincinnati, O.* James M. Allen, M.E., Lecturer on Steam Generation, *Hartford, Conn.* Rudolf Hering, C.E., Lecturer on Sanitary Engineering, *Chicago, Ill.* Horace See, M.E. Lecturer on Marine Engineering, *Philadelphia, Pa.* Elihu Thompson, E.E., Lecturer on Electrical Engineering, *Lynn, Mass.* Charles Wilson Copeland, M. E., Lecturer on the Progress of Steam Engineering, *New York City.* William Petit Trowbridge, M.A., Lecturer on Mechanics, *New York City.* Alexander Graham Bell, M.A., Lecturer on Telephony, *Washington, D.C.* Theobald Smith, Ph. B., M.D., Lecturer on Pathogenic Bacteria and their Relation to Hygiene, *Washington, D.C.*

MATERIAL EQUIPMENT OF THE UNIVERSITY.

Buildings.

The Civil Engineering Building is a large structure, three stories high, containing twenty-one rooms, with a floor surface of about eighteen thousand square feet. The western façade of the main building is one hundred and twenty feet long; the northern and southern wings are each one hundred and five feet. The building contains laboratories, museums, and class-rooms. The museums and laboratories are described elsewhere. Room 1 contains the working library of the department—some twelve hundred modern works on civil engineering, classified for ready reference. There are a reading and seminary room for students, two large lecture rooms, one fifty-two feet long by forty-five feet wide; two large draughting rooms, fitted with one hundred and fifteen improved iron desks and well lighted by day and by night; a room for meteorological observations, nearly all the instruments in which are self-registering, and several smaller lecture-rooms, store-rooms, etc.

A temporary astronomical observatory has been erected directly east of the main building, in which are mounted on brick piers, an astronomical transit by Troughton and Sims, provided with two collimators; a sidereal clock, a four-and-a-half inch Clark equatorial, and an altazimuth reading to seconds by levels and micrometers.

The trustees of the University, at a recent meeting, provided for the erection of a new building to be occupied jointly by the departments of civil engineering and architecture. This building will probably be two hundred feet long, by forty wide, four stories in height, and is intended to be ready for use by the beginning of the next collegiate year.

The Sibley College.—The buildings of Sibley College were all erected and presented to the University by the Hon. Hiram Sibley, of Rochester, N. Y., who also gave the machinery, and the greater part of all the collections with which they are supplied. The main building is of Ithaca stone trimmed with a fine white sandstone, and in its architecture is similar to the other buildings of the University. It is one hundred and sixty feet long, forty feet in width, and three stories in height. The workshops form three sides of a quadrangle, of which the fourth side is formed by the college building proper; they are of brick and one story in height. The main building contains on the first floor two large museums, which are fully described elsewhere, a large and well-lighted lecture-room, and the private rooms of the professor of practical mechanics. On the second floor are the lecture-room of the professor of mechanical engineering and the director, with its collections of illustrative materials, the drawing-rooms of the upper classes, and the private rooms of the director and professor of mechanical engineering and of the instructor in marine engineering. The third floor is filled with drawing-rooms for the younger classes in freehand drawing and decorative art, and the private rooms of the professor of drawing and his assistants. The workshops consist of a machine shop, a foundry, a blacksmith shop, and a wood-working shop, and include rooms devoted to the storage of tools, to emery-grinding, etc. These shops are from forty to sixty feet in length, about forty feet in width, and are lofty and well-lighted. An additional building, one hundred and fifty feet by forty in dimensions, and two stories in height, was completed in the summer of 1887. Its second floor is devoted to the work in machine design, and includes several drawing-rooms, a lecture-room, and a room appropriated to the use of the professor having charge of the laboratories. The main floor is divided into several rooms, each devoted to some department of experimental work, as to steam engine trials, to tests of boilers, to determination of the strength and other useful qualities of the materials of engineering. The tools and machinery are described fully under the head of Sibley College Collections. At the bottom of Fall Creek gorge is the house protecting the turbine which supplies the power demanded for ordinary occasions in driving the machinery of the college and the electric apparatus for lighting the campus and the buildings.

The Chemical and Physical Building.—This building, situated on the north side of the quadrangle, was opened for occupancy in September, 1883. It is of red sandstone, about one hundred and forty feet in length, with a width of fifty and seventy feet, and

is three stories in height above a well-lighted basement. The building is ornamented with casts and medallions of distinguished scientists. The rooms of the physical department occupy the first floor and the basement. The second and third floors are occupied by the chemical department. The building contains, in addition to the amply-equipped laboratories, two large lecture-rooms, one for chemistry and one for physics, seating about one hundred and seventy students each. A fire-proof one-story annex, built of brick, has lately been erected north of the chemical and physical building for the further extension of the work of the chemical department. This addition is one hundred feet in length by thirty-seven feet in width, and contains the laboratories of organic chemistry and assaying, with the necessary balance rooms, store-room and reading-room. It is so placed with reference to the main building as to inclose a partly paved court, suitable for experiments in the open air.

The Architectural collection contains over two thousand photographic prints, the most of which are of large size; several hundred drawings; and about two hundred models in stone and wood. These are all designed to illustrate the constructive forms and peculiarities of the different styles of architecture. These, as well as the White Architectural Library—containing over one thousand volumes—are all freely accessible to the student of architecture.

The Chemical Museum is located in a large room in the eastern end of the Chemical and Physicial building, and contains the Silliman collection of minerals, and the collection of applied chemistry. The former comprises about three thousand five hundred specimens, many of them of extreme rarity. The latter consists of materials and products illustrating many of the applications of chemistry to the arts and manufactures, such as the manufacture of soap, sulphuric acid, soda ash, alum, white lead, gunpowder, pottery, porcelain, glass, cement, dyes, pigments, oils, the refining of petroleum, etc., etc. These collections are being constantly and rapidly increased by gifts and purchases.

The Special Museums of the Civil Engineering Department contain the following collections, which receive regular additions from a yearly appropriation. 1. The Muret collection of models in descriptive geometry and stone-cutting. 2. The De Lagrave general and special models in topography, geognosy, and engineering. 3. The Schroeder models in descriptive geometry and stereotomy, with over fifty brass and silk transformable models made in this department after the Oliver models. 4. The Grund collections of bridge and track details, roofs, trusses, and masonry, supplemented by similar models by Schroeder and other makers. 5. A modern railroad bridge of one hundred feet span, the scale being one-fourth of the natural size. 6. The Digeon collection of working models in hydraulic engineering. 7. Working models of water wheels. 8. Several large collections of European and American photographs of engineering works during the process of construction, and many other photographs, blue prints, models and diagrams. 9. An extensive collection of instruments of precision, such as a Troughton and Simms astronomical transit; a universal instrument, by the same makers, reading to single seconds; sextants, astronomical clocks, chronographs, a Negus chronometer, two equatorials—the larger having an objective, by Alvan Clark, four and a half inches in diameter—and other instruments, like pier collimators, etc., necessary to the complete equipment of a training observatory. 10. A Geodesic collection, consisting of a secondary base line apparatus made under the direction of the Coast Survey, and all the portable, astronomical, and field instruments needed for extensive triangulations, including sounding-machines, tachometers, deep-water thermometers, heliotropes, etc. 11. Among the usual field instruments there is nearly every variety of engineers' transits, theodolites, levels, solar and other compasses, omnimeters, and tachometers, with a large number of special instruments, such as planimeters, pantographs, elliptographs, arithmometers, computing machines, altazimuths, sextants, hypsometers, and meteorological instruments of all descriptions.

The Museums and collections of the Sibley College of Mechanical Engineering and Mechanic Arts are of exceptional extent, value and interest. The two principal rooms on the first floor of the main building are devoted to the purposes of a museum of illustrative

apparatus, machinery, products of the manufacturing industries, and collections exhibiting processes and methods of manufacture, new inventions, the growth of standard forms of motors, and other collections of value in the courses of technical instruction given in the college. In the west museum are placed the Reuleaux collection of models of kinematic devices and movements, which is, so far as known, the only complete collection on this continent, and is one of the very few in the world. Besides these are the Schroeder and other models, exhibiting the forms and proportions of parts of machinery, the construction of steam engines and other machines, and methods of making connections. In the east museum are placed a large number of samples of machines constructed by the best makers, to illustrate their special forms and methods of manufacture. Among these are several beautifully-finished samples of steam pumps, "sectioned" to exhibit their internal construction and arrangement, steam-boiler injectors similarly divided, governors for steam engines, water-wheels and other motors, devices for lubrication, shafting and pulleys, couplings and other apparatus for the transmission of power, both by shafting and by wire-rope transmission. The lecture-rooms of the Sibley College, each being devoted to a specified line of instruction and list of subjects, are each supplied with a collection of materials, of drawings, and of models and machines, especially adapted to the wants of the lecturer in each subject. Thus, the lecture-room of the instructor in "Materials of Engineering" contains a fine collection of samples of all the metals in common use in the arts, with samples of ores and of special intermediate products, exhibiting the processes of reduction and manufacture. Among these are specimens of the whole range of copper-tin and copper-zinc alloys, and of the "kalchoids" produced by their mixture, such as were the subjects of investigations made by the Committee on Alloys of the U. S. Board appointed by President Grant by authority of Congress, in the year 1875. The collection is supplemented by other alloys later produced by the Director, and is one which has no known superior, and is perhaps unequalled The course in machine design is illustrated by the standard forms of parts of machinery. The course of instruction in mechanical engineering is illustrated by a fine collection of steam engines of various well-known types, gas and vapor engines, water-wheels and other motors, models and drawings of every standard or historical form of prime mover, of parts of machines, and of completed machinery.

The collections of the Department of Drawing include a large variety of studies of natural and conventional forms, shaded and in outline, geometrical models, casts and illustrations of historical ornament.

The workshops are supplied with every needed kind of machine or tool, including lathes, of our own and other makes, and hand and bench tools sufficient to meet the wants of over one hundred students of the first year, in woodworking; in the foundry and the forge all needed tools for a class of eighty in the second year; in the machine shop, lathes from the best builders, and others made in the University shops, planes, drills, milling machines, and a great variety of special and hand-tools, which are sufficient to work a class of sixty or seventy of the third year and fifty or sixty seniors.

The department of Experimental Engineering possesses experimental engines and boilers, and other heat motors, such as air and gas engines, and is well supplied with testing machines in considerable variety, as well as all the apparatus required, as indicators, dynamometers, etc., for determining the efficiency of engines. Each of the several rooms on the first floor of the Sibley College annex is a museum of apparatus.

Extensive special collections of apparatus have been obtained for the work in Electrical Engineering. In addition to the extensive collections of the department of Physics for ordinary laboratory instruction, that department possesses a large number and considerable variety of larger apparatus, including the great tangent galvanometer, and the outfit of the magnetic observatory, and several Gramme and other dynamos. In the Sibley College, also, are a number of dynamos, including an Edison, a Mather, a Westinghouse alternating machine, and Weston dynamos, ranging from the smallest sizes up to a six hundred and fifty light alternating current machine, all placed either in the dynamo-room in the rear of the main building or in a room adjacent to the machine shop where the very considerable power demanded can be most conveniently furnished.

A Bracket "cradle" dynamometer and a resistance coil measuring up to a twenty-two hundred ohms and four ampères, and the tangent galvanometer measuring from a fraction of an ampère to two hundred fifty ampères supply the means of making quantitative measurement of heavy currents.

Laboratories.

The Chemical Laboratories occupy a portion of the second story and the whole of the third story of the physicial and chemical building, and also the new chemical annex. On the second floor adjoining the chemical lecture-room is the laboratory for blowpiping and mineralogy, which is equipped with tables covered with porcelain tiles, and will accommodate seventy students. In the same room is a working collection of minerals comprising all of the more common species. In the third story, occupied by the department of agricultural and analytical chemistry, are two large student laboratories; one of these, for beginners in chemical practice, can accommodate one hundred students; a shaft from the ventilating-fan in the basement conveys a supply of fresh air to the room; the fume and hydrogen sulphide closets are ventilated by means of special flues heated by gas-burners. The laboratory for quantitative chemical work has places for seventy students; each place is supplied with reservoir and distilled water, gas and suction for filtration produced by the air pump in the basement. Tables for distillation, combustion, etc., at each end of the room are supplied with gas and water, and with suction, blast, oxygen and hydrogen from the works in the basement. Steam evaporating and drying closets, and fume closets, are easily accessible from all parts of the room. There are, besides the rooms already described, weighing and reading-rooms, the private laboratories of the professors, and a number of rooms for special experiments.

The new annex contains the laboratories of organic chemistry and of assaying. The organic laboratory contains slate-topped tables for twenty-four students, and is fitted up with all modern appliances for original research in this important field. Adjoining the laboratory are the store-rooms, private laboratory and the balance and reading-room, where a large part of the chemical section of the University Library, including complete sets of all the important chemical journals, is deposited. The assay laboratory contains six crucible furnaces, one large and two small muffle furnaces, one Fletcher gas cupel furnace, anvil, steel rolls, and the tools used in the various operations of assaying ores of the precious metals. In designing the Chemical Annex, the intention has been to concentrate in that building all work involving any risk of fire. With this in view, all partitions have been constructed of brick, the tables covered with slate slabs, and the floors laid with asphalt pavement.

The General Civil Engineering Laboratory occupies room No. 3 in the engineering building. The laboratory is furnished with machines for tests of materials in tension, compression, flexure, and torsion. It also contains a seconds pendulum, chronograph, models referring to the theory of the arch, thermometer tester, sections of beams and columns, tools, etc., and a small turbine, which furnishes power for the experiments of the laboratory. Room No. 4, in the same building, is the hydraulic laboratory, to which water is supplied, either from a large tank on the floor above, or directly from the mains of the University waterworks. This laboratory contains various hydraulic machines, all kinds of mouth-pieces, long and short tubes, pipes of various lengths and diameters, bends, valves, accumulators, equalizers, manometers, etc. Its facilities for contributing to the efficiency of teaching hydraulics and for original research are constantly increasing. The first floor of this laboratory contains two large setting tanks and sifting machines, used in connection with the tests on the strength of hydraulic mortars and cements, which are being conducted here in a systematic and thorough manner, and on a large scale, by the Fellows of this Department. This room is connected electrically with the astronomical observatory and with the chronographs and clocks in room No. 3, and in the department of Physics. It contains several piers, in brick and cement, for the adjustment of instruments and for practice in the observations for magnetic field-work, etc. Arrangements have been made for the swinging of a cold pendulum in the

astronomical observatory, and a hot one in the basement of the Physical Laboratory, for the discussion of the field gravimetric work in connection with the Cornell University Surveys.

The Mechanical Laboratory, which is the department of demonstration and experimental research of Sibley College, and in which not only instruction but investigation is conducted, is located in the annex of Sibley College, in several rooms of good height, well lighted on all sides, and carefully fitted up for the purpose for which they are designed. It occupies the whole lower floor, a space one hundred and fifty feet long by forty feet wide, and represents the latest contributions of Mr. Sibley to the University. It is supplied with the apparatus of experimental work in the determination of the power and efficiency of the several motors, including steam engines, and the turbine driving the machinery of the establishment; with boiler-testing plant and instruments; and with a number of machines for testing lubricants and the strength of metals. Among these is the "autographic testing machine," which produces an autographic record of the result of the tests of any metal which may be placed within its jaws, securing exact measures of the strength, the ducility, the elasticity, the resilience or shock-resisting power, the elastic limit, etc., of the material. Several steam-engines and boilers, air and gas machines, several kinds of dynamometers, lubricant-testing machines, standard pressure-gauges, and other apparatus and instruments of precision employed by the engineer in such researches as he is called upon, in the course of his professional work, to make, are all collected here.

The Physical Laboratory.—The rooms of the physical department occupy the first floor and the basement of the chemical and physical building. Piers are provided in several of the rooms for apparatus requiring immovable support, and some of the basement rooms have solid floors of cement, upon any part of which galvanometers, etc., may be used. The lecture-room on the first floor has fixed seats for one hundred and fifty-four students. The arrangements for experimental demonstrations are most complete. Gas, water, steam, oxygen, hydrogen, compressed air, blast, and vacuum cocks are within easy reach of the lecturer, and dynamo and battery currents are always at hand, and under complete control from the lecture-table. A masonry pier, four by twelve feet, permits the use in the lecture-room of apparatus that could otherwise only be used in the laboratory. A small turbine on the lecture table furnishes power for a variety of experiments. Lanterns with the lime or electric light are always in readiness for use when their use can in any way aid a demonstration. Adjacent to the lecture-room are the apparatus rooms, serving also, in part, as laboratories. On the same floor are other laboratory rooms, among which may be mentioned one for photometry, without windows, and painted black throughout.

The equipment of the physical department comprises many fine instruments of precision. The standard clock, having Professor Young's gravity escapement, is placed in a room provided with double walls, and actuates two chronographs by which the time observations of the laboratory are recorded. A very perfect automatic dividing engine, a large comparator, a standard yard and meter, an electro-calorimeter of a platinum wire resistance in a hard rubber tank, a spectrometer reading to seconds, sets of resistance coils, and galvanometers of various forms are among the instruments. For magnetic and other measurements by the magnetic needle, a special building free from iron has been erected. In these are placed the magnetometers and the instruments for the accurate measurement of currents and potentials. Of the latter is the large tangent galvanometer, constructed at the University, with coils respectively one and six-tenths and two meters in diameter, and giving deflections to ten seconds. Several dynamos of different styles and capacities, ranging from one thousand to ten thousand watts, and a special engine for driving them, having a governor adjusted to control the speed with extreme precision, are included in the equipment. Three of these dynamos are mounted on Professor Brackett's dynamometer cradles, for measuring the power absorbed, or transmitted if the machine is used as a motor. For dynamo tests a resistance of naked German silver wire has been provided, which is arranged in about one hundred sections

capable of combination in all possible ways. Combined in series they furnish a resistance of 2,200 ohms, capable of carrying four ampères. A very valuable adjunct is a well-equipped workshop connected with the department, where a skilled mechanician is constantly employed in making apparatus. Some of the most valuable instruments in the collection have been made in this shop.

The University Library.

The Library, including the President White collection, described below, contains about ninety-five thousand seven hundred volumes, besides twenty-six thousand pamphlets. It is made up largely of the following collections, increased by annual additions of from three thousand to five thousand volumes: A selection of about five thousand volumes purchased in Europe in 1868, embracing works illustrative of agriculture, the mechanic arts, chemistry, engineering, the natural sciences, physiology, and veterinary surgery; the Anthon Library, of nearly seven thousand volumes, consisting of the collection made by the late Professor Charles Anthon, of Columbia College, in the ancient classical languages and literatures, besides works in history and general literature; the Bopp Library, of about twenty-five hundred volumes, relating to the oriental langnages and literatures, and comparative philology, being the collection of the late Professor Franz Bopp, of the University of Berlin; the Goldwin Smith Library, of thirty-five hundred volumes, comprising chiefly historical works and editions of the English and ancient classics, presented to the University in 1869 by Professor Goldwin Smith, and increased during later years by the continued liberality of the donor; the publications of the Patent Office of Great Britain, about three thousand volumes, of great importance to the student in technology, and to scientific investigators; the White Architectural Library, a collection of over a thousand volumes relating to architecture and kindred branches of science, given by President White; the Kelly Mathematical Library, comprising eighteen hundred volumes and seven hundred tracts, presented by the late Hon. William Kelly, of Rhinebeck; the Cornell Agricultural Library, bought by the Hon. Ezra Cornell, chiefly in 1868; the Sparks Library, being the library of Jared Sparks, late president of Havard University, consisting of upwards of five thousand volumes and four thousand pamphlets, relating chiefly to the history of America; the May collection, relating to the history of slavery and anti-slavery, the nucleus of which was formed by the gift of the library of the late Rev. Samuel J. May, of Syracuse; the Schuyler collection of folklore, Russian history and literature, presented by the Hon. Eugene Schuyler in 1884; the Law Library, containing over four thousand volumes of legal works, purchased by the University in 1886. The number of periodicals and transactions, literary and scientific, currently received at the Library, is four hundred and thirty five, and of many of these complete sets are on the shelves.

The British Patent Office and the United States Patent Office supply all reports published by them; a very large number of mechanical and engineering periodicals are taken, and some progress has been made toward collecting a library of books of similar character.

Physics.

Lecture Courses in Elementary Physics.

The instruction in the elements of Physics is by means of lectures given twice a week throughout the year. In these lectures the general laws of mechanics and heat, electricity and magnetism, and of acoustics and optics, are presented. The very large collection of lecture-room apparatus possessed by the department, makes it possible to give experimental demonstrations of all important phenomena. The course of lectures is supplemented by weekly recitations, for which purpose the class is divided into sections of about twenty members each.

Two courses are given, one of which is intended for students in Science and Letters, in Agriculture, and in the course preparatory to Medicine; the other for students in Civil, Mechanical and Electrical Engineering, in Architecture and in Chemistry and

Physics. The ground covered in these courses is essentially the same, but the methods of treatment differ : being adapted in each case to the needs and previous training of the class of students for which the course is designed. The successful completion of the freshman mathematics is in all cases a pre-requisite for admission to these courses.

Courses of Laboratory Instruction.

The first year of Laboratory work is devoted to the experimental verification of physical formulæ, to practice in the use of instruments of precision, and to the attainment of some knowledge of the simpler mothods of physical manipulation.

In Mechanics the student is taught the proper use of the miscroscope and of various forms of micrometer, of the cathetometer, dividing engine, comparator, analytical balance and chronograph ; and of other instruments for the measurement of length, mass and time. In Heat the course includes methods of testing thermometers, the use of the calorimeter and thermopile, and practice determinations, by various methods, of melting and boiling points, of specific heat and the heat of fusion and vaporization. In Optics the elementary laboratory instruction embraces the use of the spectroscope and spectrometer, the determination of wave-lengths, the measurement of lenses and prisms, and of indices of refraction ; together with a variety of other experiments calculated to familiarize the student with the fundamental principles of the subject. In Electricity the work consists of the adjustment and calibration of galvanometers, of the verification of the principles upon which the measurements of current, electro-motive force and resistance are based, the use of the electrometer, and the performance of such other experiments as offer the best preparation for advanced work in electricity. In Magnetism practice determinations are made of the magnetic dip and of the horizontal intensity and variations in the direction and intensity of the earth's magnetism ; and the student makes a preliminary study of the methods of measuring the magnetic field.

Advanced students make a more extended study of varions physical constants. They learn the use of standard instruments, make electrical and magnetic determinations in absolute measure; test the efficiency and determine the characteristics of dynamo machines. The opportunities afforded for advanced work in electricity are unusual.

Every encouragement is afforded to advanced students for the carrying on of original investigations, and every opportunity is taken to stimulate a spirit of scientific enquiry. Courses of reading are suggested to such students, in connection with their experimental work ; and they are brought together informally at frequent intervals for the discussion of topics of scientific interest. It is the aim of this department to furnish every possible facility for research in Physics on the part of students qualified to do original work.

Chemistry.

I. Descriptive and Theoretical Chemistry.

To students in the general courses, and others who can devote but little time to the study of chemistry, instruction is given by a course of lectures and recitations on the principles of the science and general study of the chemistry of inorganic substances.

Students who propose to take up subsequently analytical and organic chemistry are given a distinct course of lectures and recitations, and in addition are required to perform in the laboratory an extended series of simple experiments illustrating the principles discussed in the lectures. They are thus brought into close contact with the phenomena to be studied, and the impression produced by the principles stated is greatly deepened.

The instruction in theoretical chemistry is continued by lectures and recitations in chemical philosophy, and also, in connection with laboratory work, in organic and analytical chemistry.

II. Analytical Chemistry.

Elementary Qualitative Analysis.—The course in elementary qualitative analysis occupies about two terms of seven to ten hours a week of actual practice, the work in

the laboratory being supplemented by lectures and recitations. It is the purpose of this class-room work—of which practice in writing chemical equations explanatory of the operations and reactions of the actual analytical work forms an important feature—to give the student some acquaintance with the chemical principles upon which that work is based, so that he may carry it out more intelligently and successfully than if he blindly follows the directions in the text-book.

Blowpipe Analysis and Determinative Mineralogy.—A course of instruction in qualitative blowpipe analysis and determinative mineralogy is given during one term. This is designed to enable the student to avail himself of the simple and effective means afforded by the blowpipe in determining the natnre of minerals and unknown chemical substances.

The work in determinative mineralogy comprises the identification of minerals by observation of their physical properties and blowpipe reactions, and constitutes a necessary preparation for the study of systematic mineralogy and lithology. This course is followed by one term of the study of systematic mineralogy, comprising lectures, conferences, and the study of specimens. The subject of crystallography forms an important part of this course, and includes lectures illustratcd by a complete set of glass models, as well as laboratory practice in the identification of crystalline forms, from blocks and actual specimens.

Exceptional advantages for the study of mineralogy are offered by the well-known Silliman collection of minerals, which is accessible to students at all times. A complete and carefully selected student's collection affords abundant material for work in determinative mineralogy. Special attention is given to the more important metallic ores as a preparation for the study of economic geology and metallurgy.

Students who have completed the above course are prepared to take up the work of lithology, petrography, and advanced crystallography, for which abundant facilities are offered in the department of geology.

Elementary Quantitative Analysis.—This course extends for all students through at least one term of ten hours of actual practice, and comprises a small number of simple gravimetric and volumetric determinations, together with some required study of the chemistry of the operations involved. Beyond this the work of each student is adapted to the particular purpose for which it is taken.

Agricultural Chemistry.—Students in the Course in Agriculture have practice in the analysis of fertillizers and feeding materials, of foods, of dairy products, and of waters used for the household.

Engineering Chemistry.—The student in the Course of Mechanical Engineering may, if he can give more time to chemical practice than is allotted to his course, work on the analysis of iron and steel, and of other materials used in the mechanic arts.

Medical Chemistry.—Practice is given to students in the medical preparatory course in the analysis of urine, milk, of water used for drinking. in the separation of mineral and vegetable poisons from animal matter, and their identification, and the assay of medicinal preparations.

Pharmaceutical Chemistry.—Students in the Course in Pharmacy will take practice in all the kinds of analysis mentioned in the preceding course, and also in the assay of the crude materials used in the manufacture of drugs and medicinal preparations.

Sanitary Chemistry.—The student of Sanitary Science takes practice in the examination of drinking water, of air in connection with the study of the ventilation of rooms, of illuminating oils, and the detection of injurious adulterations of foods and beverages, or the injurious qualities of other articles in common use.

The Full Course in Quantitative Analysis in the Wet Way.—The student in the Course in Chemistry, besides taking all work above mentioned, is drilled also in the methods of analysis of ores, the useful metals in their commercial condition—especially iron and steel—of alloys and of gaseous mixtures; in the use of the polariscope and spec-

troscope, so far as they can be profitably applied in chemical analysis, the analysis of technical products, the examination of articles of food and drink for adulterations of commercial as well as sanitary significance, etc.

To these students lectures are given on the recent literature of chemical analysis; and readings are held in German chemical journals, for the purpose of giving such a familiarity with technical German that the abundant and important literature of the subject in that language can be consulted with facility.

Assaying.—In assaying students are required to determine the value of gold, silver, and other metals contained in ores, sufficient in number to make them familiar with the most approved methods in use in the West and in European mining regions. The assay of gold and silver bullion, as practised in the national mints, forms a part of the course. The assay laboratory is equipped with every requisite for work in this branch.

III. Organic Chemistry.

The elements of organic chemistry are taught by a course of laboratory practice with frequent recitations, by which the student is trained not only to recognize, but also to prepare and purify, the typical members of most of the series of organic compounds. In this course the work is arranged in accordance with the well-known text-book of Professor Remsen. After its completion students are given further practice in following out reactions of special theoretical interest, in the course of which constant reference is made to the original memoirs, published in the leading German and French periodicals. As soon as the necessary proficiency in manipulation and theoretical knowledge is attained, the student is given every encouragement to devote himself to original investigation, for which organic chemistry offers an especially promising field. A special laboratory of organic chemistry has just been completed, and equipped with an unusually complete stock of materials and apparatus.

IV. Applied Chemistry.

This subject is taught by a course of lectures, continuing throughout the year, on the principles of chemical manufacture and the important chemical industries. The course is supplemented and continued by special work in the analytical and organic laboratories, by which the student is trained in the special determinations and operations of the particular industry to which he may intend to devote himself.

V. Metallurgy.

During the winter term of the Junior year two lectures a week are devoted to metallurgy. These lectures are intended to give the students in the technical courses a general idea of fuels, ores, and the most important methods of extracting the metals which are especially used in construction, the metallurgy of iron naturally claiming the most attention.

Architecture.

The instruction is given by means of lectures and practical exercises. Its object is not merely to develop the artistic powers of the student, but to lay that foundation of knowledge without which there can be no true art. Drawing is taught during the first two years, and afterward thoroughly used and applied in mechanics, stereotomy and designing.

Architectural mechanics occupies a part of each term for one year. The lectures are each supplemented by at least two hours of work on problems. In developing the subjects and in solving problems, analytical methods are used; but for practical use special attention is paid to the application of graphical statics.

The study of the history of architecture and the development of the various styles runs through five terms. The lectures are illustrated by photographs, engravings, drawings, casts, and models, of which the supply for the use of the department, is very large.

Proper attention is paid to acoustics, ventilation, heating, decoration, contracts, and specifications. The whole ground of education in architecture, practical, scientific, historical, and æsthetic, is covered as completely as is practicable in a four year course.

Civil Engineering.

The several courses of preparatory and professional studies have been planned with a view to laying a substantial foundation for the general and technical knowledge needed by practitioners in civil engineering; so that our graduates, guided by their theoretical education and as much of engineering practice as can be taught in schools, may develop into useful investigators and constructors.

The aim of this department is mainly to make its pupils cultured and well balanced professional men, trained to meet the actual demands of American engineering science and practice, without losing sight of the necessity of fostering professional progress.

The prominent characteristic of the organization of this department is the care exercised in the choice of its officers of instruction. The advanced mathematics, which have a prominent place in all the courses; the graphics, field operations, economics of engineering, and investigations in the library and laboratories of the department are, with only two exceptions, in charge of a body of instructors who are specialists in their respective branches, and who join to a long training as teachers, the professional experience derived from active service in charge of construction for periods ranging between nine and twenty-five years; they are thus competent to judge of the needs and best methods for promoting the usefulness of this school. It is the duty of these officers to study closely, and contribute to the advancement of their several specialties; and through their acquaintance with the engineering problems of the day and consultation with the Dean of the department, secure a proper balance between the various elements which enter into the technical education of the civil engineer. As the result of this system of administration, and of the success met in years past by heeding the growing tendency to specialize, within the means at our disposal at present, it has been necessary to add to the general training of the undergraduate course, five additional one year courses for graduates, These graduate courses are constantly growing in strength and attracting a steadily increasing number of resident graduates. Under certain restrictions as to the number of students, the graduate courses are open to civil engineers of this or other institutions having undergraduate courses similar to our own, and offer courses of advanced and special studies in the following departments: Bridge Engineering, Railroad Engineering, Sanitary and Municipal Engineering, Hydraulic Engineering, and Geodetic Engineering. The object of these courses is to provide the young graduate with the means of prosecuting advanced investigations after such experience in professional life as may lead him to decide in the choice of a specialty. Lectures in the museum and laboratories are given to these students for the purpose of directing and aiding their original researches. All graduate work may alternate with a limited number of elective studies in other professional schools, or in history, literature and general science; but the choice of electives implies suitable preparation for their prosecution, and must, besides, meet with the approval of the Dean of this department.

The work of the students in the undergraduate courses is based upon an extended course on the mechanics, and the graphics and economics of engineering. There are no elective studies in these courses. The object aimed at is to give as thorough a preparation as possible for the general purposes of the profession in the following subjects: The survey, location, and construction of railroads, canals, and water works; the construction of foundations in water and on land, and of superstructures and tunnels; the survey, improvements, and defenses of coasts, rivers, harbors and lakes; the astronomical determination of geographical co ordinates for geodetic purposes; the application of mechanics, graphical statics, and descriptive geometry to the construction of the various kinds of right and oblique arches, bridges, roofs, trusses, suspension and cantilever bridges; the drainage of districts, sewering of towns, and the reclaiming of lands; the design, construction, application and tests of wind and hydraulic motors; air, electrical, and heat

engines, and pneumatic works; the preparation of plans and specifications, and the proper inspection, selection, and tests of the materials used in construction. An elementary course of lectures is given in engineering and mining economy, finance and jurisprudence. The latter subject deals only with the questions of easements and servitudes, as digested from Washburn, and to the ordinary principles of the laws of contracts and riparian rights.

The facilities for instruction and for advanced investigations are believed to be thorough and efficient. Laboratory work is required of the students, in chemistry, mineralogy, geology, physics, and civil engineering; for which purpose all the libraries, collections, and laboratories of the University are open to the students of this department.

The organization of this department is correlated with that of others through some of its departments of instruction, and with great mutual advantage. Thus, this department teaches descriptive geometry to all students in the courses in Civil Engineering, Architecture, Electrical and Mechanical Engineering; and this subject may be elected by students in some of the general and scientific courses, and by special students. The theory of the arch and stone cutting, with its corresponding laboratory work, is taken by students in Architecture and Civil Engineering. Land Surveying is obligatory for Civil Engineers, and may be elected by students of various other courses. The entire course in mechanics, hydraulics and hydraulic motors, is taken by the civil engineering students; and the electrical and mechanical engineering students have the first three terms, or the mechanics of engineering of solids. The higher mathematical studies and the purely professional studies may be elected by any graduates having the necessary preparation.

The Sibley College of Mechanical Engineering and the Mechanic Arts.

This college has been founded and endowed by the liberal gifts of the Hon. Hiram Sibley, of Rochester, N.Y., who in the year 1870 gave about thirty thousand dollars for the erection of a suitable building for the Department of Mechanic Arts. He also gave ten thousand dollars for increasing its equipment of tools, machines, etc., and afterward made a further gift of fifty thousand dollars for the endowment of the Sibley professorship of practical mechanics and machine construction. During the years 1883 to 1887 he gave more than seventy-five thousand dollars for the purchase of models, the extension of the Sibley College buildings, and the building and equipping of a complete set of workshops. The total amount thus presented to Cornell University is nearly one hundred and fifty thousand dollars.

Sibley College is the School of Mechanical Engineering and of Mechanical Arts, of Cornell University. The college is divided into three principal departments: that of Mechanical Engineering, including a Laboratory, in which experimental work and investigations are conducted; a department of Mechanic Arts, or shopwork; and a department of Drawing and Machine Design. The first-named is presided over by the Director, who is also the Professor of Mechanical Engineering.

Regular Course.

Sibley College, founded as a college of the Mechanic Arts, is intended by the Trustees of the University to be made not only a school of arts and trades, but a college of mechanical engineering, also in which schools of the mechanic arts and of the various branches of mechanical engineering shall be developed, as rapidly and extensively as the means placed at the disposal of the Trustees of the University, and a demand for advanced and complete courses of instruction, shall allow.

I. Department of Mechanical Engineering.

The Department of Mechanical Engineering is divided into two principal sections: that of Theoretical Engineering and that of Experimental Engineering, or the Mechanical Laboratory.

(1) *Section of Theoretical Engineering* :—The lecture-room course of instruction consists of the study, by text-book and lecture, of the materials used in mechanical engineering; the valuable qualities of these materials being exhibited in the mechanical laboratory by the use of the various kinds of testing machines, as well as by examination of specimens of all the most familiar grades, of which samples are seen in the cases of the museums and lecture-rooms. The theory of strength of materials is here applied, and the effects of modifying conditions—such as variation of temperature, frequency and period of strain, method of application of stress—are illustrated. This course of study is followed, or accompanied, by instruction in the science of pure mechanism or kinematics, which traces motions of connected parts, without reference to the causes of such motion, or to the work done, or the energy transmitted. This study is conducted largely in the drawing-rooms, where the successive positions of moving parts can be laid down on paper. It is illustrated, in some directions, by the set of kinematic models known as the Reuleaux models, a complete collection of which is found in the museums of Sibley College.

The study of machine design succeeds that of pure mechanism, just described. This study also is largely conducted in the drawing-rooms, and is directed by an instructor familiar, practically as well as theoretically, with the designing and proportioning of machinery.

The closing work of the course consists of the study, by text-book and lecture, of the theory of the steam engine and other motors. The last term of the regular four-year course is devoted largely to the preparation of a graduating thesis, in which the student is expected to exhibit something of the working power and the knowledge gained during his course. A *graduating piece* is demanded, also, of each student, both in the drawing-room and the workshop, which shall show proficiency in those departments.

(2) *Section of Experimental Engineering, or Mechanical Laboratory Instruction* :—The work in this department will be conducted by an instructor familiar with its apparatus and with the best methods of work, and who will plan a systematic course of instruction that is intended to give the student not only skill in the use of apparatus of exact measurement, but to teach him also the best methods of research, and to give him a good idea of the most effective methods of planning and of prosecuting investigations, with a view to securing fruitfulness of result with minimum expenditure of time and money.

II. Department of Mechanic Arts, or Shopwork.

The aim of the instruction in this, the department of Practical Mechanics and Machine Construction, is to make the student, as far as time will permit, acquainted with the most approved methods of construction and inspection of machinery.

(1) *Section of Wood-working and Pattern-making* :—This course begins with a series of exercises in woodworking. each of which is intended to give the student familiarity with a certain application of a certain tool; and the course of exercises, as a whole, is expected to enable the industrious, conscientious, and painstaking student to easily and exactly perform any ordinary operation familiar to the carpenter, the joiner, and the pattern-maker. Time permitting, these prescribed exercises are followed by practice in making members of structures, joints, and of small complete structures, and of patterns, their core-boxes, and other constructions in wood. Particular attention will be paid to the details of pattern-making.

(2) *Section of Blacksmithing, Moulding, and Foundrywork* :—These courses are expected not only to give the student a knowledge of the methods of the blacksmith and the moulder, but to teach him also how to use the tools and to give him that manual skill in the handling of tools which will permit him to enter the machine shop, and there quickly to acquire familiarity and skill in the manipulation of the metals, and in the management of both hand and machine tools, as used in the working of such metals.

(3) *Section of Ironworking* :—The instruction in the machine shop, as in the foundry, and the blacksmith shop, is intended to be carried on in substantially the same

manner as in the woodworking course, beginning by a series of graded exercises, which will give the student familiarity with the tools of the craft and with the operations for the performance of which they are particularly designed, and concluding by practice in the construction of parts of machinery, and, time permitting, in the building of complete machines which may have a market value.

III. Department of Industrial Drawing and Art.

(1) *Section of Freehand Drawing and Art*:—Instruction in this department begins with Freehand Drawing, which is taught by means of lectures and general exercises from the blackboard, from flat copies, and from models. The work embraces a thorough training of the hand and eye in outline drawing, elementary perspective, model and object drawing, drawing from casts, and sketching from nature.

The course in freehand drawing is followed, where time permits, by instruction in industrial art, in designing for textiles and ceramics, in modelling, and in other advanced studies introductory to the study of fine art.

(2) *Section of Mechanical Drawing*:—The course of instruction in Mechanical Drawing is progressive, from machine-sketching and geometrical drawing to designing of machinery and making complete working drawings.

The course begins with freehand drawing, as above; and in the latter part of this work considerable time is expected to be given to the sketching of parts of machines and of trains of mechanism, and later, of working machines. The use of drawing instruments is next taught, and, after the student has acquired some knowledge of descriptive geometry and the allied branches, the methods of work in the drawing-rooms of workshops and manufacturing establishments are learned. Line drawing, tracing and blue printing, the conventional colors, geometrical constructions, projections, and other important details of the draughtsman's work, are practised until the student has acquired some proficiency.

The advanced instruction given the upper classes includes the tracing of curves and cams, the study of kinematics on the drawing-boards, tracing the motions of detail-mechanism, and the kinematic relations of connected parts. This part of the work is accompanied by lecture-room instruction and the study of the text-book, the instructors in the drawing-rooms being assisted by the lecture-room instructor, who is a specialist in this branch. The concluding part of the course embraces a similar method of teaching machine design, the lecture-room and drawing-room work being correlated in the same manner as in kinematics or mechanism. The course concludes, when time allows, by the designing of complete machines, as of the steam engine or other motor, or of some important special type of machine.

Industrial Art.

A four years' course of instruction in Industrial Art is arranged for students having a talent for such work, and desiring to devote their whole time to this subject. No degree is conferred, but a certificate of proficiency may be given at the end of the course.

Electrical Engineering.

The student, at the end of the third year may, if he choose, substitute this work for that of the regular course.

The course of study for the first three years is the same as that of Mechanical Engineering, comprising drawing, mathematics, mechanics, mechanism, machine design, the elementary study of physics, and preliminary practice in the use of electrical and other instruments. The special work of the fourth year comprises the study of prime-movers, the theory and construction of electrical machinery, the study of the problems involved in the distribution of the electric light and the electrical transmission of power, besides practice in every variety of electrical measurement and testing, as applied to the erection and maintenance of electric lighting plants and telephone and telegraph lines and cables, and to the purposes of investigation.

Graduates in the course in Electrical Engineering are given the degree of Mechanical Engineer as in the regular course ; and a statement that the student has paid special attention to electrical work is introduced into his diploma.

Graduate Courses.

Electrical Engineering.—A graduate course is arranged for students in Mechanical Engineering who desire further instruction in Electrical Engineering.

Marine Engineering.—At the request of the University, an officer of the engineer corps of the United States Navy has been detailed for the purpose of giving instruction in Mechanical and Marine Engineering. Special work in this subject may therefore be taken by such students as desire it. This instruction is given in a graduate or fifth-year course, after the student shall have completed the regular course in Mechanical Engineering or obtained its equivalent elsewhere.

Mining Engineering.—Although Mining Engineering courses have not been formally established, the main instruction required by the mining engineer is now given, as follows : the professor of civil engineering and his associates pay especial attention to the needs of those intending to connect themselves with the mining industries, giving lectures on tunnelling and on the theory and practice of such constructions as are common to the professions of civil and mining engineer ; the professor of mechanical engineering and his associates pursue a like course, giving instruction in mining machinery ; the professors of general chemistry and mineralogy, and of analytical chemistry, give instruction in metallurgy, assaying, chemical analysis, and cognate subjects ; the professors of geology and paleontology give instruction in the theory and classification of ores, and in those branches relating to chemical geology.

Steam Engineering.—Special instruction in Steam Engineering is provided for advanced students and educated practising engineers who have pursued the course of study in the school of mechanical engineering or its equivalent, and who are thus fitted to profit by instruction in this line of special professional work. The course of instruction is an extension of the work of the senior year in mechanical engineering, and includes the study of steam engines and boilers and their accessory apparatus, for the purpose of learning the theory and practice of engineering as applied to this class of motors.

Railroad Machinery.—This graduate department is intended to prepare the same class of students as the schools already described, for special work in railroad shops, and especially in the division of the organization of railways placed in charge of superintendents of motive power, and of master mechanics. All students taking this and the preceding courses should have the same preparation as is required in the course in Marine Engineering.

"*Special*" *or Artisan Course.*—All special students are expected to follow as closely as possible a course of instruction in the mechanic arts and allied studies, planned with reference to the needs of such students, and of young men not candidates for a degree, who are able to enter on the optional list, passing the primary examinations.

Non-resident Lecturers.—A room for a lyceum is fitted up for the use of students enrolled in Sibley College, in which weekly debates are carried on.

Supplementing the regular course of instruction, lectures are delivered from time to time by the most distinguished men of the profession.

The course in architecture extends over two years, and consists of instruction in Linear Drawing and Projection, Building Materials and Construction, Shades, Shadows and Perspective, Mechanics of Building, History of Architecture, Designing, Decoration and Acoustics, together with a very thorough course in Drafting.

The course in Civil Engineering consists of instruction in Linear Drawing, Lettering, Descriptive Geometry, Pen Topography, Colored Topography, Mechanics of Engineering, Shades, Shadows, Perspective and Tinting, Structural Details, Elementary Designing, Railroad Surveying and Economics, Bridge Stresses, Bridge Designing, Bridge

Construction, Spherical Astronomy, Stereotomy and Theory of the Arch, Hydraulics, Geodesy, Theory and Designing of the Oblique Arch and Stone Cutting, Hydraulic Motors, Engineering Economics, Hydrographic Mapping and Chart Making, Geodetical Practice, Laboratory Practice and Drafting.

Mechanical Engineering—The course in Mechanical Engineering consists of lectures in Kinematics and Mechanism, Materials of Construction, Machine Design, Steam Engines and other motors, Thermodynamics and the Theory of the Steam and other Heat Engines, Structure and Operation of Engines, Steam Generation, etc. Industrial Drawing and Art, Mechanical Laboratory.

In addition to the ordinary course in Civil and Mechanical Engineering, there is also a graduate course in Railroad Engineering, Sanitary Engineering, Hydraulic Engineering, Geodetic Engineering, Electrical Engineering, Marine Engineering, Mining Engineering, Steam Engineering, and Railroad Machinery.

Course in Architecture—Mechanics, Trusses, Arches, Strength of Materials, and Geodetric Engineering, Egyptian, Greek and Roman Architecture, Designing, Byzantine and Romanesque Architecture, Decoration, Gothic, Architecture, Photography, Renaissance Architecture, Stereotomy, Modern Architecture, Military Service, Acoustics, Ventilation, Warming, Measuring, Contracts and Specifications, Professional Practices, and Modelling.

LEHIGH UNIVERSITY.

Lehigh University is situated in the City of Bethlehem, in Southern Pennsylvania, in the midst of the great iron mining district of the State. It was established by the Hon. Asa Packer, of Mauch Chunk, who in 1865, appropriated the sum of Five Hundred Thousand Dollars, to which he added one hundred and fifteen acres of land in South Bethlehem, to establish an educational Institution in the rich and beautiful Valley of the Lehigh. From this foundation rose the Lehigh University, incorporated by the Legislature of Pennsylvania in 1866. In addition to these gifts, made during his life-time, Judge Packer by his last will secured to the University an endowment of $1,500,000, and to the University Library one of $500,000.

The original object of Judge Packer was to afford the young men of the Lehigh Valley a complete technical education for those professions which had developed the peculiar resources of the surrounding region. Instruction was to be liberally provided in Civil, Mechanical and Mining Engineering, Chemistry, Metallurgy, and in all needful collateral studies. French and German were made important elements in the collegiate course. A School of General Literature was part of the original plan, together with tuition in the ancient Classics.

Free Tuition.

All its educational facilities are provided without charge. Through the generosity of the Founder, the Trustees were enabled, in 1871, to declare tuition free in all branches and classes. The Lehigh University is open to young men of good character and suitable preparation from every part of the United States, and of the world.

Faculty.

The Faculty consists of seven Professors and fourteen Instructors in the Technological Department alone, as follows:—

Robert A. Lamberton, LL.D., President.

Henry Coppée, LL.D., Professor of English Literature, International and Constitutional Law, and the Philosophy of History.

William H. Chandler, Ph.D., F.C.S., Professor of Chemistry.
Benjamin W. Frazier, M.A., Professor of Mineralogy and Metallurgy.
H. Wilson Harding, M.A., Professor of Physics.
Charles L. Doolittle, C.E., Professor of Mathematics and Astronomy.
William A. Lamberton, M.A., Professor of the Greek Language and Literature.
Mansfield Merriman, C.E., Ph.D., Professor of Civil Engineering.
Severin Ringer, U.J.D., Professor of Modern Languages, Literature, and History.
Henry C. Johnson, M.A., LL.B., Professor of the Latin Language and Literature.
Edward H. Williams, Jr., B.A., E.M., A.C., Professor of Mining Engineering and Geology.
Joseph F. Klein, D.E., Professor of Mechanical Engineering, and Secretary of the Faculty.
The Rev. Albert W. Snyder, B.D., Professor of Psychology and Christian Evidences.

Lecturer.

William L. Estes, M.D., Lecturer on Physiology and Hygiene.

Instructors.

Spencer V. Rice, C.E., Instructor in Drawing.
Arthur E. Meaker, C.E., Instructor in Mathematics.
Harvey S. Houskeeper, B.A., Instructor in Physics.
Preston A. Lambert, B.A., Instructor in Mathematics.
William K. Gillett, M.A., Instructor in Modern Languages.
Fonger De Haan, C.N.L., Instructor in Modern Languages.
Lester P. Breckenridge, Ph.B., Instructor in Mechanical Engineering.
Henry S. Jacoby, C.E., Instructor in Civil Engineering.
Fred. Putnam Spalding, C.E., Instructor in Civil Engineering.
James B. Mackintosh, E.M., C.E., Instructor in Quantitative Analysis.
Charles N. Lake, Ph.C., Instructor in Qualitative Analysis and Assaying.
George F. Duck, E.M., Instructor in Mining.
Edwin F. Miller, M.E., Instructor in Mechanical Engineering.
Fayette B. Petersen, C.E., Instructor in Metallurgy and Mineralogy.
Charles W. Marsh, Ph.D., Instructor in Organic and Industrial Chemistry.
Joseph W. Richards, M.A., A.C., Assistant Instructor in Metallurgy and Blowpiping.

Gymnasium.

Director, (Vacant.)
Assistant, Charles F. Seeley.

Library.

William H. Chandler, Ph.D., Director.
A. W. Sterner. Chief Cataloguer.
Wilson F. Stauffer, Cataloguing Clerk.
Peter F. Stauffer, Shelf Clerk.

Buildings.

Packer Hall,

named after the Founder, stands seven hundred feet back of Packer Avenue, at the base of the South Mountain. It is built of stone and contains Lecture and Recitation Rooms, the Drawing Rooms and the Museum of Geology and Natural History.

The Chemical Laboratory

is thoroughly fire-proof, is built of sandstone, and is 219 feet in length by 44 in width.

There are two principal stories and a basement. The upper floor is occupied by the quantitative and the qualitative chemical laboratories, the former accommodating 48 and

the latter 84 students. These rooms are 20 feet in height, and are well lighted and ventilated. A laboratory for industrial chemistry and the supply room are also on this floor.

The first floor contains a large lecture room, a recitation room, a chemical museum and laboratories for organic, physiological, agricultural and sanitary Chemistry.

In the basement is the large laboratory for the furnace assay of ores and a well-appointed laboratory for gas analysis, also rooms containing the apparatus for several processes in industrial chemistry, the engine and air-pump for vacum filtration, a storeroom and the toilet.

A photographic laboratory is located in the third story of the central portion of the building,

The Metallurgical Laboratory

contains a lecture room, a blowpipe laboratory for class instruction in blowpipe analysis and in the practical determination of crystals and minerals, a museum for mineralogical and metallurgical collections, a mineralogical laboratory provided with a Fuess reflecting goniometer, a polariscope, a Groth's "universal apparat" and a Rosenbusch polarizing microscope, a dry laboratory provided with furnaces for solid fuel and for gas with natural draught and with blast, and a wet laboratory for ordinary analytical work. It is arranged for the instruction of classes in the courses of mineralogy, metallurgy and blowpipe analysis of the regular curriculum, and to afford facilities to a limited number of advanced students to familiarize themselves with the methods of measurement and research employed in mineralogy and metallurgy, and to conduct original investigations in these departments of science.

The Physical Laboratory

consists of three stories. A large lecture room with a seating capacity of 150, occupies a portion of the second and third floors. It is well lighted and adapted to its purposes. On the remainder of these floors are two rooms, each 40 feet long, for Heat and Light laboratories, a dark room for photographic work, spectroscopic and apparatus rooms and the private laboratories of the instructors.

The lower floor is devoted to the use of the students in Electricity. A large room nearly 40 feet square is used as the Electrical Laboratory There are smaller rooms for photometric and spectroscopic work, also reading, balance, apparatus and engine rooms. On this floor a 12 horse-power high speed engine and a dynamo supply two systems of electric lights, one of 25 incandescent lamps, the other of four arc lights, for practical tests in the Electrical Laboratory and for experimental purposes in the lecture room above. In the cellar are battery, storerooms, etc.

The tower and two rooms in the east end of Christmas Hall have been given to the Departments of Physics and will be equipped as a Meteorological Observatory.

The Sayre Observatory.

Near Brodhead Avenue is the Sayre Observatory, the gift of Robert H. Sayre, Esq., of South Bethlehem, containing an equatorial and a zenith telescope, transit instrument and astronomical clock.

The University Library.

To the East of Packer Hall is the University Library, erected by the Founder in memory of Mrs. Lucy Packer Linderman, his daughter.

The Gymnasium

is a handsome and spacious structure, built and equipped with the utmost thoroughness. It is furnished with the best patterns of gymnastic apparatus, besides Dr. Sargent's system of Developing appliances. It is provided with hot and cold water ; tub, sponge and shower baths, and 329 clothes closets. Opportunities for recreation and amusement are provided in the billiard room and bowling alleys. It is under the immediate care of a skilled and competent Director.

All students are required to undergo a physical examination before being allowed the use of the Gymnasium, and this examination will be repeated once each year during their stay at the University. The proper exercise is prescribed and is required of every student. The aim of the Institution is to promote a harmonious symmetrical development best suited to the individual condition of the student.

Admission of Students.

Entrance Examinations.

Examinations for admission to the University are held at the opening of each term, and also in June at the close of the Academic year.

Character of the Examinations.

The examinations are rigorous and cover the entire ground laid down in the following scheme. They are all conducted in writing, supplemented by an oral examination at the option of the examiner.

All candidates for admission must be at least sixteen years of age, must present testimonials of good moral character; and, must satisfactorily pass in the following subjects:

1. *English Grammar*, including composition, spelling and punctuation. It is recommended that candidates have a knowledge of Latin Grammar, although an examination in it is not required for any courses except the Classical and the Latin-Scientific.

2. *Geography*, general and political.

3. *History of the United States*, including the *Constitution.*

4. *Arithmetic*, including the metric system of weights and measures.

5. *Algebra*, Fundamental Principles. Factoring. Least Common Multiple. Greatest Common Divisor. Fractions. Involution. Evolution. Radicals. Imaginary Quantities. Equations of the First and Second Degrees. Ratio. Proportion and Progressions.

6. *Geometry*, Fundamental Principles. Rectilinear Figures. The Circle. Proportional Lines and Similar Figures. Comparison and Measurement of the Surfaces of Rectilinear Figures. Regular Polygons. Measurement of the Circle. Maxima and Minima of Plane Figures. The Plane and Polyhedral Angles.

For admission to the various courses, *in addition* to the requirements above given, the examinations include:

7. *Elementary Physics.*

Special Students.

Young men who do not desire to take a full regular course can enter and select special shorter courses, with the sanction of the Faculty; but in all cases satisfactory examinations must be passed upon the subjects required for admission to the Freshman class.

Admission to Advanced Studies.

Candidates for admission to advanced studies *in any course* are required to pass, *in addition to the entrance examinations for that course*, examinations in the work already done by the classes which they desire to enter. These examinations are held on the same days as those for admission to the Freshman class.

Admission to the Post Graduate Course.

Students of this University who have taken their *first* degree, and others, on presenting a diploma of an equivalent degree conferred elsewhere, are admitted to advanced studies, according to the plan to be found under the general subject of Graduate Students.

Freshman Class.

First Term.

Mathematics.—Chauvenet's Geometry (completed).

Chemistry.—Lectures. Fownes' Elementary Chemistry.

German.—Brandt's Grammar. Lodeman's Manual of Exercises. Writing in German text. Translations into English. Or *French.*—Chardenal. Keetel's Analytical Reader.

Drawing.—Elementary Projections, Shading and Lettering. Descriptive Geometry.

English.—Exercises and Declamations.

Physiology and Health.—Lectures.

Gymnasium.

Second Term

Mathematics.—Olney's University Algebra, Part III. Plane and Spherical Trigonometry and Mensuration. Use of Logarithmic Tables.

Surveying.—Theory of Chain and Compass Surveying. Computation of Areas. Elements of Levelling.

German.—Grammar and Exercises (continued). Joyne's Otto's Reader. Translations. Or *French.*—Grammar. Keetel's Reader. Translations.

Drawing.—Projection Drawing and Descriptive Geometry. Freehand drawing.

English.—Exercises and Declamations.

Gymnasium.

Sophomore Class.

First Term.

Mathematics.—Analytical Geometry : Olney's General Geometry.

Physics.—Mechanics, Heat, and Electricity. Lectures.

German.—Grammar. Exercises. Translations. Readings. Or *French.*—Grammar. Chardenal's Exercises. Readings. Translations.

Drawing.—Isometric Drawing. Architectural Drawing.

Surveying.—Use of the Compass, Level and Transit. Surveys and Maps of Farms. Colored Topography.

English.— Exercises and Declamations.

Gymnasium.

Second Term.

Mathematics.—Differential and Integral Calculus : Olney.

Physics.—Sound, Light and Meteorology. Lectures.

German.—Grammar. Exercises. Systematic Readings. Translations. Dictation. Or *French.*—Grammar. Dictation. Chardenal's Exercises. O'Connor : Choix de Contes Contemporains.

Mechanics.—Mathematical Theory of Motion. Science of Motion in General. Statics. Dynamics, and Statics of Fluids. Lectures on the Theory of Centre of Gravity and Moment of Inertia.

Surveying.—Profiles and Contour Maps. Hydrographic and City Surveying. Use of the Plane Table. Topographical Drawing.

Essays and Declamations.

Gymnasium.

Junior Class.

First Term.

Mathematics.—Integral Calculus: Courtenay.

German.—Systematic Readings. Translation. Dictation. Compositions. Or *French.*—Translation. Readings. Contemporary Authors. Saintsbury: Specimens of French Literature. Conversation Class in both languages optional.

Surveying.—Triangulation. Levelling. Topographical Surveying with Transit and Stadia. Topographical Map.

Strength of Materials.—Elasticity and Strength of Wood, Stone and Metals. Theory of Columns, Shafts and Beams. Reports on the Testing of Materials.

Construction.—Materials of Construction. Masonry. Foundations. Construction of Roads and Pavements.

Crystallography.—Lectures, with practical exercises in the determination of Crystals.

Literature and History.

Gymnasium.

Second Term.

German.—Systematic Readings. Compositions. Lectures on German Literature. Or *French.*—Reading. Dictation. Compositions. Lectures on French Literature.

Surveying.—Theory of Railroad Curves. Railroad Reconnaissance and Location. Survey of a Line, with Profile, Map and Estimate of cost.

Roofs and Bridges.—Theory and Calculation of Strains in Roof and Bridge Trusses.

Construction.—Stone cutting, with Practical Drawings. Construction and Maintenance of Railroads. Theory of Retaining Walls and Stone Arches.

Mineralogy.—Descriptive Mineralogy, with Practical Exercises in the Determination of Minerals.

Essays and Original Orations.

Gymnasium.

Senior Class.

First Term.

Astronomy.—Loomis' Treatise, with Lectures.

Graphical Statics.—Analysis of Stresses in Roof Trusses, Bridge Trusses and Arches.

Bridges.—Suspension, Continuous and Cantilever Bridges. Design of an Iron Bridge, with Working Drawings.

Surveying.—Use of Solar Transit and Sextant.

Mechanics of Machinery.—Pile Drivers, Cranes and Elevators. The mechanics of the Locomotive.

Geology.—Lithology, with practical exercises in determining rocks.

Gymnasium.

Second Term.

Astronomy.—Doolittle's Practical Astronomy, with Observatory Work.

Surveying.—Elements of Geodesy. The Figure of the Earth. Map Projections. Elements of the Method of Least Squares.

Hydraulics.—Hydrostatics. Efflux of water from orifices, and flow in pipes and rivers. Hydraulic motors.

Hydraulic and Sanitary Engineering.—Collection, Purification and Distribution of Water. Systems of Water Supply. The Combined and the Separate System of Sewerage. Disposal of Sewage. House Drainage. Hydraulic Experiments.

Geology.—Historic and dynamic. Le Conte.

Lectures on Engltsh Literature.

Christian Evidences.—Lectures.

Preparation of Thesis.

Gymnasium.

The Course of Mechanical Engineering.

The object of this course is the study of the Science of Machines. The principal subjects taught are: The nature, equivalence and analysis of mechanisms, the mechanics or theory of the principal classes of types and machinery, Mechanical Technology and the principles and practice of Machine Design.

That the students may obtain the practical engineering data which they will most need when beginning their work as mechanical engineers, they are required to pursue a course of Shop Instruction which does not necessarily involve manual labor and manipulation of tools, but is principally devoted to familiarizing them with those points in pattern-making, moulding, forging, fitting and finishing, which they need to know as designers of machinery. Particular attention is therefore directed to the forms and sizes of machine parts that can be readily constructed in the various workshops, to the time that it takes to perform, and the order of, the various operations, to the dimensions most needed by workmen and to the various devices for increasing the accuracy of the work, durability of the parts and convenience of manipulation. This involves acquaintance with the processes and machinery of the workshops, but it is the foreman's and superintendent's knowledge which is required rather than the manual dexterity and skill of the workman and tool hand. The acquirements peculiar to the latter are by no means despised, and students are encouraged to familiarize themselves therewith during leisure hours, but manual work in the shops forms no regnlar part of the course. On the contrary, the student enters the shop with hands and mind free to examine all the processes, operations and machinery, and is ready at the call of the teacher to witness any operation of special interest. Provided with note-book, pencil, calipers and measuring rule, the student sketches the important parts of the various machine-tools, notes down the successive steps of each of the important shop-processes as illustrated by the pieces operated upon, and follows pieces of work through the shops from the pig or merchant form to the finished machine.

That the students may learn to observe carefully and be trained to think and observe for themselves in these matters, there is required of them a full description of the various processes, operations and tools involved in the production of each one of a series of properly graded examples of patterns, castings, forgings and finished pieces which are not being constructed in the shops at the time and the blue prints for which have been given to them on entering the shops. The student's work is directed not only by these drawings and by the printed programme given him at the start, but also personally by a teacher, who accompanies him into the shops, gives necessary explanations, and tests the extent and accuracy of his knowledge by examining the sketches and notes and by frequent questioning. Finally the results of the observations and the sketches are embodied in a memoir.

During the course there are frequent visits of inspection to engineering works, both in and out of town, with special reference to such subjects as Machine Elements, Prime Movers, Machinery for lifting, handling and transporting, and Machinery for changing the form and size of materials. It is intended that each of these excursions shall have some definite purpose in view which must be fully reported upon by the students.

The instruction in Machine Design, during the second term of the Junior year, consists in determining rational and empirical formulas for proportioning such machine parts

as come under the head of fastenings, bearings, rotating, sliding and twisting pieces, belt and toothed gearing, levers and connecting rods, also in comparing recent and approved forms of these same parts with respect to their advantages as regards fitness, ease of construction and durability, and in making full-sized working drawings of these parts; all the dimensions are determined by the students from the above-mentioned formulas, the data being given as nearly as possible as they would arise in practice. During the Senior year the students undertake the calculations, estimates and working drawings involved in the design of a simple but complete machine, each student being engaged upon a different machine. From the finished drawings of each machine, tracings are made and then blue prints taken for distribution among the other members of the class. The whole class also takes up the design of a steam engine, every dimension being determined by the students, and complete working-drawings made. In the case of the simple machines and of the steam engine, the general plan or arrangement will be given to the students in the form of rough sketches, photographs or wood-cuts. This work will continue to the middle of the last term of the Senior year. From this time on the students are expected to make original designs for simple mechanisms, whose object has been fully explained. Throughout the course the work in the draughting room is carried on as nearly as possible like that of an engineering establishment, and special attention is paid to methods of expediting the work of calculation by means of simple formulas, tables and diagrams.

The graduate in this course will receive the degree of Mechanical Engineer (M.E.).

Freshman Class.

Second Term.

Mathematics.—Olney's University Algebra, Part III. Plane and Spherical Trigonometry and Mensuration. Use of Logarithmic Tables.

German.—Grammar and Exercises (continued). Joynes' Otto's Reader. Translations. Or *French.*—Grammar. Keetel's Reader. Translations.

Drawing.—Projection Drawing and Descriptive Geometry. Freehand Drawing.

English.—Exercises and Declamations.

Gymnasium.

Sophomore Class.

First Term.

Mathematics.—Analytical Geometry: Olney's General Geometry.

Physics.—Mechanics, Heat and Electricity. Lectures.

Drawing.—Isometrical Drawing. Architectural Drawing.

Visits of Inspection.—Shops of the vicinity.

German.—Grammar. Exercises. Translations. Readings. Or *French.*—Grammar. Chardenal's Exercises. Readings. Translations.

English.—Exercises and Declamations.

Gymnasium.

Second Term.

Mathematics.—Differential and Integral Calculus: Olney.

Physics.—Sound, Light and Meteorology. Lectures.

German.—Grammar. Exercises. Systematic Readings. Translations. Dictation. Or *French.*—Grammar. Dictation. Chardenal's Exercises. O'Connor: Choix de Contes Contemporains.

Mechanics.—Mathematical Theory of Motion. Science of Motion in general. Statics. Dynamics and Statics of Fluids. Lectures on Theory of Centre of Gravity and Moment of Inertia.

Steam Engine.—Rigg's Practical Treatise.

Essays and Declamations.

Gymnasium.

Junior Class.

First Term.

Mathematics.—Integral Calculus : Courtenay.

German.—Systematic Readings. Translation. Dictation. Compositions. Or *French.*—Translations, Readings. Contemporary authors. Saintsbury : Specimens of French Literature. Conversation Class in both languages optional.

Mechanical Technology.—Shop instruction. Examination of the processes and appliances involved in pattern-making, moulding, forging, fitting and finishing, with sketches and reports.

Boilers.—Wilson. Strength, construction and wear and tear of boilers.

Strength of Materials.—Elasticity and strength of wood, stone and metals. Theory of beams, shafts and columns. Reports on experimental tests.

Literature and History.

Gymnasium.

Second Term.

German.—Systematic Readings. Compositions. Lectures on German Literature. Or *French.*—Reading. Dictation. Compositions. Lectures on French Literature. Conversation Class in both languages optional.

Kinematics of Machinery.—Reuleaux. Nature and Equivalence of Mechanisms.

Machine Design.—Proportioning of such machine parts as come under the head of fastenings, bearings, rotating and sliding pieces, belt and toothed gearing, levers and connecting rods.

Metallurgy.—Metallurgical Processes. Furnaces. Refractory Building Materials. Combustion. Natural and Artificial Fuels. Metallurgy of Iron.

Machinery of Transmission.—Weisbach-Herrmann.

Essays and Original Orations.

Gymnasium.

Senior Class.

First Term.

Thermodynamics.—General principles ; application to Steam Engines and Air Compressors.

Graphical Statics.—Graphical Analysis of Roof Trusses and Girders.

Machine Design.—Calculations and working-drawings for a High-speed Steam Engine.

Kinematics.—Diagrams of the changes of position, speed and acceleration in mechanisms. Link and valve motions. Quick return motions. Parallel motions. Laying out of Cams.

Mechanics of Machinery.—Weisbach-Herrmann. Hoisting Machinery, Accumulators, Cranes and Locomotives.

Gymnasium.

Second Term.

Mechanics of Machinery.—Weisbach-Herrmann. Pumps, Pumping Engines, Blowing Engines, Compressors and Fans.

Machine Design.—Calculations and working-drawings for the following machines: Drilling, Shaping, Milling, Shearing and Punching Machines, Hoists, Pumps and Stone Crushers. Original Designs.

Hydraulics.—Hydrostatics. Flow of water in pipes and channels; hydraulic motors.

Measurement of Power.—Indicating of Steam Engines; determination of evaporative efficiency of boilers; dynamometer experiments.

Lectures on American and English Literature.

Christian Evidences.—Lectures.

Preparation of Thesis.

Gymnasium.

The Course in Mining and Metallurgy.

This course aims to fit the student for practical work in either of the branches of Mining, Metallurgy, Metallurgical Chemistry, or Geology. On account of the great number and scope of the studies necessary to the completion of this course, it is five years in length. At the completion of the fourth year the student will have completed a course similar to that leading to the Scientific degree in other institutions and will receive the degree of Bachelor of Science in Mining and Metallurgy (B.S.).

The graduate in this course will receive the degree of Engineer of Mines (E.M.), which includes that of Metallurgist.

Chemistry.—The course in Theoretical and Applied Chemistry extends over three years and includes the methods of wet and dry Assaying and Blowpipe analysis combined with the working of Stoichiometric problems and the Study of Chemical Philosophy. The practical work is that required for a Metallurgical Chemist or Assayer.

Metallurgy.—This course extends over one year and, after treating of the principles of the subject, enters minutely into the processes for the extraction and separation of metals from ores, with details of the necessary plants required and costs of extraction. A special laboratory attached to this department affords practical work in metallurgical problems.

Geology.—Three terms are devoted to Crystallography, Mineralogy, and Macroscopic Lithology. In each study, after a grounding of the theory of the subject, there is an extended course in practical determination of the most important species. There are from three to four hundred specimens to illustrate the first study, and from three to five thousand hand specimens for each of the two latter. A year is then given to dynamic, historic and economic Geology, and this is supplemented by field work and the construction of maps and sections.

Astronomy.—After studying the theory of the subject, two-thirds of the year are devoted to practical work in the Observatory.

Applied Mechanics.—This embraces Hydraulics, a study of the Steam Engine and the mechanics of machines employed in Mining and Metallurgy.

Surveying.—A course extending over five terms offers practice in land, mine, and geological surveying, levelling, topography, triangulation, and railroad reconnaissance and location, It also includes practical work in drawing and map construction.

Mining.—This course covers the theory and practice of locating and winning deposits with a full discussion of and practice in the engineering problems occurring in Mining, such as haulage, pumping, ventilation and hygiene, ore-dressing, and mining Law. A series of projects supplement the problems and give practical studies in Mining and Metallurgy.

The location of the University in the vicinity of the iron works of the Lehigh Valley and especially of the extensive establishment of the Bethlehem Iron Company, affords unusual facilities for the practical study of iron metallurgy. The processes for the manufacture of spelter and oxide of zinc may be studied at the Bethlehem Zinc Works. The facilities for the practical study of mining and economic geology are not excelled by those of any other Institution in the country. The zinc mines at Friedensville and the brown hematite and slate deposits of the Lehigh Valley are in the immediate vicinity, while within easy reach by rail are the anthracite coal fields of Pennsylvania, the iron and zinc mines of New Jersey, and the celebrated iron mines at Cornwall, Pa.

Freshman Class.

Second Term.

Mathematics.—Olney's University Algebra, Pt. III. Plane and Spherical Trigonometry and Mensuration. Use of Logarithmic tables.

German.—Grammar and Exercises (continued). Joyne's Otto's Reader. Translations. Or *French.*—Grammar. Keetel's Reader. Translations.

Drawing.—Projection Drawing and Descriptive Geometry. Freehand Drawing.

Surveying.—Theory of Chain and Compass Surveying, Computation of Areas and Levelling.

English.—Exercises and Declamations.

Gymnasium.

Sophomore Class.

First Term.

Mathematics.—Analytical Geometry: Olney's General Geometry.

Physics.—Mechanics, Heat and Electricity. Lectures.

German.—Grammar. Exercises. Translations. Reading. Or *French.*—Grammar. Chardenal's Exercises. Readings. Translations.

Drawing.—Isometric Drawing. Architectural Drawing.

Surveying.—Use of the Level and Transit. Surveys and Maps of Farms. Colored Topography.

English.—Exercises and Declamations.

Gymnasium.

Second Term.

Mathematics.—Differential and Integral Calculus: Olney.

Mechanics.—Mathematical Theory of Motion. Science of Motion in general. Statics. Dynamics and Statics of Fluids. Lectures on Theory of Centre of Gravity and Moment of Inertia.

Chemistry.—Lectures and Laboratory Practice. Douglass and Prescott's Qualitative Analysis.

Stoichometry.

German.—Grammar Exercises. Systematic Readings. Translations. Dictations. Or *French.*—Grammar. Dictation. Chardenal's Exercises. O'Connor: Choix de Contes Contemperains.

Essays and Declamations.

Gymnasium.

Junior Class.

First Term.

Mathematics.—Integral Calculus : Courtenay.

Strength of Materials.—Elasticity and strength of wood, stone and metals. Theory of beams, columns snd shafts.

Crystallography.—Lectures, with Practical Exercises in the determination of Crystals.

Surveying.—Triangulation. Levelling. Topographical Surveys with Transit and Stadia. Topographical Maps.

Chemical Philosophy.—Cooke.

German.—Systematic Readings. Translation. Dictation. Compositions. Or *French.*—Translation. Readings. Contemporary Authors. Saintsbury : Specimens of French Literature. Conversation Class in both languages optional.

Literature and History.

Gymnasium.

Second Term.

Mineralogy.—Descriptive Mineralogy, with Practical Exercises in the Determination of Minerals : E. S. Dana.

Blow-Pipe Analysis.—Lectures, with Practice. Plattner, Brush, or Nason and Chandler.

Chemistry.—Fresenius' Quantitative Analysis. The following analyses are executed by the student :

1. Iron Wire (Fe)
2. Copper Ore (Cu)
3. Silver Coin (Au, Ag, Pb, Cu)
4. Zinc Ore (Zn) By both Gravimetric and Volumetric Methods.
5. Bronze (Cu, Sn, Zn, Pb)
6. Spiegeleisen (Mn)
7. Lead Ore (PbS)
8. Ilmenite (TiO_2)
9. Iron Ore (Complete Analysis)

Steam Engine.—Rigg's Practical Treatise.

Surveying.—Theory of Railroad curves. Railroad Reconnaissance and Location. Survey of a Line, with Profile, Map and Estimate of cost.

German.—Systematic Readings. Compositions. Lectures on German Literature Or *French.*—Reading. Dictation. Compositions. Lectures on French Literature. Conversation Class in both languages.

Essays and Original Orations.

Gymnasium.

Senior Class.

First Term.

Thermodynamics.—General principles; application to Steam Engines and Air Compressors.

Geology.—General Geological Definitions and Principles. Dynamic Geology.

Lithology.—Theory, with practical exercises in determining rocks.

Chemistry.—Quantitative Analysis : Laboratory Work : Fresenius. The following analyses are executed by the student :

10. Limestone (Complete Analysis)
11. Coal (Violate Matter, Fixed Carbon, Ash, H_2 O, S, P)
12. Slag (Complete Analysis)
13. Pig Iron (Complete Analysis)
14. Carbon in Steel (Volumetric)
15. Nickel Ore (Ni, Co)
16. Gas Analysis.

Assaying.—Including the Assay by the dry methods of Gold, Silver, Antimony, Mercury, Lead, Iron and Tin ores. Laboratory Work. Ricketts.

Second Term.

Metallurgy.—Metallurgical Processes. Furnaces. Refractory Building Materials. Combustion. Natural and Artificial Fuels. Metallurgy of Iron.

Mining.—Modes of Occurrences of the Useful Minerals. Searching for Mineral deposits. Examination of Mining Properties. Boring. Mining Tools, Machines and Processes. Timberiug and Masonry. Callon. André. Lectures.

Geology.—Historic and Economic Geology. Lectures. LeConte. Dana.

Blow-pipe Analysis.—Practice.

Hydraulics.—Hydrostatics. Flow of water in pipes and channels. Hydraulic Motors.

Surveying.—Mine Survey. Theory and Practice, with construction of Mine Maps. Tunnelling and Shaft location.

Gymnasium.

Post-senior Class.

First Term.

Metallurgy.—Of Copper, Lead, Silver, Gold, Platinum, Mercury, Tin, Zinc, Nickel, Cobalt, Arsenic, Antimony and Bismuth.

Mining.—Methods of Working. Underground Transportation. Hoisting, Drainage and Pumping. Ventilation and Lighting. Hygiene of Mines.

**Mechanics of Machinery.*—Weisbach-Herrmann. Hoisting Machinery, Accumulators, Cranes.

Astronomy.—Descriptive Astronomy : Loomis.

**Surveying.*—Geological Survey : Mapping and cross-sectioning.

Second Term.

Mining.—Mechanical Preparation of Ores. Coal Washing.

Mechanics and Machinery.—Pumps, Pumping-Engines, Blowing-Engines, Compressors and Fans.

Astronomy.—Doolittle's Practical Astronomy, with Observatory Work.

Drawing.—Mining Plant. Systems of Timbering.

Projects.—In Mining, Geology and Metallurgy.

Lectures on American and English Literature.

Christian Evidences.—Lectures.

Preparation of Thesis..

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*The Surveying is completed in the first half of the term by taking four exercises per week. The Mechanics of Machinery is then begun.

The Course in Electrical Engineering and Physics.

The degree of Electrical Engineer (E.E.) is given to the graduates of this course.

In the arrangement of the details of this course, the object has been to provide for those, who seek to fit themselves as Electrical Engineers, a preliminary training as complete and broad as that given to the members of the other schools. The requirements for admission, the mathematical and English studies. the modern languages and other outside branches are the same as those in the other technical courses. To these have been added such portions of the Mechanical Engineering Course, with which this course is most closely allied, as are necessary to give the student a general, but sufficiently accurate knowledge of machinery.

This preparation joined to the unusually full development of Physics—and especially of Electricity—will, it is thought, make a course sufficiently comprehensive and thorough for the proper training of candidates for this degree. The great success attending the large majority of young men who have taken the one year's Course in Electricity, in their subsequent electrical work, warrants the belief that this broader and more extended course will attain its object.

The main feature of this new course is the prominence given to the subject of Physics. This extends through three years and while Electricity is specially developed, the other branches, Elementary Mechanics, Heat and Light are fully provided for. The opportunity is thus given to any one, who wishes to acquire a more extensive knowledge of Physics than the University curriculum has heretofore offered. The student is well drilled in the theory by means of lectures and recitations, which carefully cover the whole subject and he is required to go over the ground himself in the best of all schools —the working laboratory. Enough of work on each topic is given him to render him familiar with his subject. Much prominence is given to work that brings out the resources of the student himself, such as the construction of instruments and original investigation. He is encouraged to this and a regular portion of his time is set apart for this object.

Freshman Class.

Second Term.

Mathematics.—Olney's University Algebra, Part III. Plane and Spherical Trigonometry and Mensuration. Use of Logarithmic Tables.

Chemistry.—Lectures and Laboratory Practice. Douglass and Prescott's Qualitative Analysis.

German.—Grammar and Exercises (continued). Joyne's Otto's Reader. Translations. Or *French.*—Grammar. Keetel's Reader. Translations.

Drawing.—Projection Drawing. Descriptive Geometry. Freehand Drawing.

English.—Exercises and Declamations.

Gymnasium.

Sophomore Class.

First Term.

Mathematics.—Analytical Geometry : Olney's General Geometry.

Mechanics, Sound and Heat.—(Theory, lectures and recitations.)

Mechanics.—(Physical Laboratory). Exact Measurements. Density. Elasticity. Tenacity. Hydrostatics. Specific Gravity. Atmospheric Pressure (with barometric levelling.) Gravitation. Moment of Inertia.

Sound.—Determination of velocities and wave lengths. Measurements of vibrations. Verifications of laws of vibrations of sounding bodies.

Heat.—Construction of Instruments. Thermometry. Expansion. Conduction. Radiation.

Drawing.—Isometrical Drawing. Architectural Drawing.

German.—Grammar. Exercises. Translations. Readings. Or *French*—Grammar. Chardenal's Exercises. Readings. Translations.

English.—Exercises and Declamations.

Gymnasium.

Second Term.

Mathematics.—Differential and Integral Calculus: Olney.

Heat.—Continued. (Physical Laboratory.) Fusion and Vaporization. Calorimetry. Hygrometry. Elementary Thermodynamics.

German.—Grammar. Exercises. Systematic Readings. Translations. Dictation. Or *French.*—Grammar. Dictation. Chardenal's Exercises. O'Connor: Choix de Contes Contemporains.

Mechanics.—Mathematical Theory of Motion. Science of Motion in general. Statics. Dynamics and Statics of Fluids. Lectures on Theory of Centre of Gravity and Moment of Inertia.

Steam Engine.—Rigg's Practical Treatise.

Essays and Declamations.

Gymnasium.

Junior Class.

First Term.

Mathematics.—Integral Calculus: Courtenay.

German.—Systematic Readings. Translation. Dictation. Compositions. Or *French.*—Translations. Readings. Contemporaneous authors. Saintsbury: Specimens of French Literature. Conversation Class in both languages optional.

Light and Magnetism.—(Theory; text-books and lectures).

Light.—(Physical Laboratory). Investigation of general Principles and Laws. Determination of Focal Lengths and Indices of Refraction, Testing and Adjustment of Optical Instruments. Spectroscopic Analysis. Photometry. Polarization. Diffraction.

Magnetism.—Fundamental Experiments. Verification of Laws of Magnets. Study and Mapping of Lines of Force. Determination of Moments of Magnets; and of horizontal component and whole intensity of Earth's Magnetism in absolute units. Distribution of Magnetism.

Meteorology.—Text-book and practice. Observations for several months as taken in the U. S. Signal Service Stations; with all the usual corrections and reductions; construction of charts; mapping curves; reports, etc.

Strength of Materials.—Elasticity and strength of wood, stone and metals. Theory of beams, columns and shafts.

Boilers.—Wilson. Strength, construction and wear and tear of boilers.

English.—Exercises and Declamations.

Gymnasium.

Second Term.

Electricity.—(Theory; text-books and lectures).

Static Electricity.—(Physical Laboratory). Investigation of Principles. Quantitative Laws. Measurements of Potential, Capacity, etc. Induction. Condensation. Analysis of Machines.

Voltaic Electricity—Management and care of a large variety of batteries. Construction of Instruments. Determination of Constants. Electro-Magnetism. Induction

Electro-Dynamics. Electrical Measurements of Potential, Resistance and Current Strength. Electrolysis. Electroplating. Electrotyping. Thermo Electricity. Secondary Batteries. Relation of Electrical Currents to Heat and Mechanical Work.

German.—Systematic Readings. Compositions. Lectures on German Literature: Deutsche Literatur. Or *French.*—Reading. Dictation. Compositions. Lectures on French Literature. Conversation Class in both languages, optional.

Machine Designs.—Proportioning of such machine parts as come under the head of fastenings, bearings rotating and sliding pieces, belt and toothed gearing, levers and connecting rods.

Literature and History.—Lectures.

Essays and Original Orations..

Gymnasium.

Senior Class.

First Term.

Dynamic Machines.—Theory, text-book and lectures. (Physical Laboratory). Practical running and care of dynamos and motors. Measurements of magnetic field, potential, resistance and heating. Visits to manufactories and working systems.

Electric Lighting.—Lectures. (Physical Laboratory). Study of different systems. Calculations and arrangement of plant. Wiring. Insulation. Photometric tests of different arc and incandescent lamps. Determination of heat units given off by various incandescent lamps; their resistance (hot and cold). Energy consumed in lamps and conductors. Spectroscopic tests of purity of carbons.

Machine Design.—Calculations for a High Speed Steam Engine.

Astronomy.—Loomis' Treatise, with Lectures.

Graphical Statics of Mechanism.—Herrmann Smith.

Scientific Readings.

Gymnasium.

Second Term.

Telegraphs and Telephone.—Investigation of different systems. Arrangement of lines and stations. Test of lines for conductivity, insulation, location of faults, etc.

Application of Electricity to Railways.—Theory of the two systems, with inspection of electric railways.

Measurement of Power.—Indicating of Steam Engines; dynamometer experiments.

Dynamic Machines.—(Physical Laboratory). Tests of Efficiency in Generators and Motors, etc.

Physics.—Original Investigation.

English Literature.—Lectures on English and American Literature.

Christian Evidences.

Preparation of Thesis.—(With Laboratory work).

Gymnaisum.

The Course in Chemistry.

This course of study is designed to prepare students for the profession of the Chemist, in connection with metallurgical establishmeuts, sugar refineries, gas works, superphosphate works, electrical machinery manufactories, mining companies, etc., and the general consulting and analytical work of the Professional Chemist. It is also well adapted for the preparation of teachers of chemistry and as a preliminary course to the study of medicine. It is eminently practical, the student's time being largely occupied by practical work in

the large, well equipped and well ventilated chemical laboratories, which were completed in 1885 and constitute the best constructed building for this purpose in this country. The museum of Chemistry contains large collections of specimens, illustrating theoretical and applied chemistry, for illustrating the lectures on these subjects.

Theoretical Chemistry.—Instruction in this subject begins with lectures four times a week, in the first term of the Freshman year; these lectures are fully illustrated by experiments, colored diagrams, working drawings and lantern pictures and specimens from the museum. These lectures include a general introduction to Theoretical Chemistry, and a description of the non-metallic and metallic elements and their compounds, the general subject of inorganic chemistry. The students are required to take notes of the lectures, and to pass a written examination at the end of the term.

In the second term of this year Stoichiometry and chemical problems and reactions are taught by recitations twice each week.

The study of Theoretical Chemistry is continued throughout the Sophomore year, by recitations three times a week from Cooke's Chemical Philosophy, and is concluded in the first term of Junior, by a course of lectures and recitations on Theoretical Organic Chemistry, four times a week. These lectures are illustrated by experiments and by specimens from the museum of Chemistry.

Written examinations are held at the close of each of the above courses.

Analytical Chemistry.—Qualitative Analysis is taught in the second term of the Freshman year, by lectures, recitations and practical work in the Qualitative Laboratory, twelve hours of practical work per week being required. This laboratory is a large, well ventilated and well lighted room, and supplied with convenient working tables, vacuum filtration, hoods for noxious vapors, steam baths, gas and washing appliances, and a commodious room for hydrosulphuric acid. Distilled water is delivered by faucet in this room and the other large laboratories. At the close of the term a practical examination is held in this subject.

After completing this course, Quantitative Analysis is taken up throughout the Sophomore and the first term of the Junior years. This subject is taught by lectures, recitations and practical work in the Quantitative Laboratory, which is equipped similarly to the Qualitative Laboratory, but is supplied in addition with apparatus for drying precipitates and residues, rooms for the chemical balances, for combustions, and for a reference library.

Twelve hours per week are required during the first term of the Sophomore year, and fifteen hours during the second term of that year and the first term of the Junior year.

The course consists in Gravimetric and Volumetric Analyses, as applied to the substances given in the lists farther on, accuracy being required in the determination of each constituent.

At the close of each term, written and oral examinations are held upon the theory and practice of Quantitative Analysis.

Gas Analysis is taught by lectures and laboratory practice in the Gas Laboratory. This laboratory is supplied with full and complete apparatus for Gas Analysis, according to Bunsen's processes, as well as apparatus for some of the more rapid methods. Mixtures of gases are required to be analyzed by the students, within certain limits of error, and a written examination, on the theory and practice, is held at the close of the course.

Assaying.—The Assaying of ores by furnace assay, together with gold and silver bullion analysis, by processes practised in the United States Mint, is taught by lectures and practical work in the first term of the Junior year, nine hours of practical work per week being required. The course includes the assaying of ores of lead, tin, antimony, gold, silver and iron, coal, and gold and silver bullion.

The Assaying Laboratory is supplied with large working tables, twenty-nine crucible and two iron furnaces, and eight muffle furnaces, with adjoining rooms for balances, and gold and silver bullion analysis.

A certain accuracy of results and a written examination as regards the theory and practice are required.

Organic Chemistry.—The practical work in this subject is performed in the second term of the Junior and first term of the Senior years, fifteen hours during the former and twelve hours during the latter term being required, with conferences and recitations each week. The laboratory for this work is equipped similarly to the Quantitative Laboratory, in addition being supplied with steam heat, cold water and air blast upon the working tables, and a full supply of apparatus for the various determinations and experiments, including combustion furnaces, furnaces for heating sealed tubes, mercury pump, Hoffman's, Dumas' and Meyers' apparatus for vapor densities, nitrometers, chemical balances, etc.

The course consists of determinations of specific gravities, melting points, boiling points, vapor densities, chlorine, bromine, iodine and sulphur of organic substances.

Combustion analysis, nitrogen determination, fractional distillation, and the preparation of several pure organic compounds and their analysis are included.

Industrial Chemistry.—A course of lectures is delivered upon this subject in the second term of the Senior year, illustrated by experiments, diagrams, lantern pictures and specimens from the museum of Chemistry. The working laboratory for this subject contains an apparatus for making illuminating gas, an alcohol still, worm and doubler, and a complete working model of a sugar refinery, including filters, vacuum pan and centrifugal. In connection with this laboratory is a room containing a photometer and apparatus for determining the sulphur, ammonia and specific gravity of illuminating gas; also a laboratory for the testing of alcoholic liquors, sugar, molasses, bone black, soap, petroleum, paints, dyes, superphosphates and other commercial products, with the necessary technical apparatus. The students make practical experiments in this direction, and, with an instructor, visit various industrial establishments in this neighborhood and in and around New York City.

Toxicology.—A course of lectures on this subject is given in the first term of the Junior year, illustrated by experiments and by the large collection of specimens of poisons from the museum of chemistry. This is supplemented by a short course of laboratory work on some of the common poisons.

Sanitary Chemistry.—During the second term of the Senior year, attention is given to the qualitative and quantitative examinations of air, water, food, disenfectants, and other subjects connected with this branch of the science. Special apparatus is provided for this work, as recommended by the best authorities on the subject.

Photographic Chemistry.—Well equipped Photographic Laboratory and dark rooms are provided, in which the students of the chemical course receive practical instruction.

Physiological Chemistry.—The examination of urine, blood, etc., receives a proper amount of attention.

The course also includes instruction in physics, mineralogy, blowpipe analysis, metallurgy and geology, which are of great value to the chemist.

In the last term of the senior year, the student is required to prepare a Thesis on some subject, selected by the Professor of Chemistry, involving practical work in the laboratory, in addition to the literary labor, each graduate thus making a contribution to the progress of the science, as a preliminary to the reception of his degree.

The graduate of this course receiving the degree of Analytical Chemist. (A.C.)

Students, not candidates for a degree, are admitted for special courses in chemistry, of which they receive certificates.

The Laboratories are under the immediate charge of the Professor and Instructors of Chemistry, and are open to the students from 8 o'clock a.m. to 6 o'clock p.m., including Saturdays. Students are at liberty to work in the Laboratories, beyond the required hours, as their time may permit. Students are charged for materials and apparatus consumed.

Freshman Class.

Second Term.

Mathematics.—Olney's University Algebra, Part III. Plane and Spherical Trigonometry and Mensuration. Use of Logarithmic Tables.

Chemistry.—Lectures and Laboratory Practice. Douglass and Prescott's Qualitative Analysis.

German.—Grammar and Exercises (continued). Joyne's Otto's Reader. Translations. Or *French.*—Grammar. Keetel's Reader. Translations.

Stoichiometry.

English.—Exercises and Declamations.

Gymnasium.

Sophomore Class.

First Term.

Chemical Philosophy.—Cooke.

Quantitative Analysis.—Fresenius' Quantitative Analysis.

The following analyses are executed by the student :—

1. Iron Wire (Fe)
2. Potassium Dichromate (Cr_2O_3)
3. Barium Chloride (Ba, Cl, H_2O)
4. Magnesium Sulphate (MgO, SO_3, H_2O)
5. Disodium Hydrogen Phosphate (P_2O_5)
6. Rochelle Salt (K_2O, Na_2O)
7. Volumetric Determination of Chlorine.
8. Acidimetry (HCl, H_2SO_4, HNO_3, $HC_2H_3O_2$)
9. Alkalimetry (KOH, NaOH, NH_4OH, Soda Ash, Pearl Ash)
10. Chlorimetry (Bleaching Powders)

Quantitative Analysis.—Conference.

Physics.—Mechanics, Heat and Electricity. Lectures.

German.—Grammar. Exercises. Translations. Reading. Or *French.*—Grammar. Chardenal's Exercises. Readings. Translations.

English.—Exercises and Declamations.

Gymnasium.

Second Term.

Physics.—Sound, Light and Meteorology. Lectures.

German.—Grammar. Exercises. Systematic Readings. Translations. Dictation. Or *French.*—Grammar. Dictation. Chardenal's Exercises. O'Connor : Choix de Contes Contemporains.

Quantitative Analysis.—Fresenius' Quantitative Analysis.

The following analyses are executed by the student :—

11. Copper Ore (Cu)
12. Zinc Ore (Zn). By both Gravimetric and Volumetric Methods.
13. Lead Ore (Pb, S)
14. Silver Coin (Au, Pb, Ag, Cu)
15. Spiegeleisen (Mm)

16. Copper Alloys. (Complete Analysis.)
17. Ilmenite (TiO_2)
18. Iron Ore (Complete Analysis)
19. Limestone (Complete Analysis)
20. Coal (Volatile Matter, Fixed Carbon, Ash, H_2O, S, P)
21. Slag (Complete Analysis)

Quantitative Analysis.—Conference.

Blow-Pipe Analysis.—Lectures, with Practice. Plattner, Brush, or Nason and Chandler.

Chemical Philosophy.

Essays and Declamations.

Gymnasium.

Junior Class.

First Term.

Toxicology.—Lectures.

Quantitative Analysis.—Fresenius' Quantitative Analysis.

The following analyses are executed by the student :—

22. Guano (NH_3, P_2O_5, H_2O)
23. Clay (Complete Analysis)
24. Manganese Ore (MnO_2)
25. Mineral Water (Complete Analysis)
26. Pig Iron (Complete Analysis)
27. Nickel Ore (Ni, Co)
28. Carbon in Steel (Volumetric)
29. Gas Analysis.

Quantitative Analysis.—Conference.

Organic Chemistry.—Lectures and Recitations.

Crystallography.—Lectures, with Practical Exercises in the Determination of Crystals.

German.—Systematic Readings. Translation. Dictation. Compositions. Or *French.*—Translation. Readings. Contemporary authors. Saintsbury: Specimens of French Literature. Conversation Class in both languages optional.

Gymnasium.

Second Term.

Organic Chemistry.—Laboratory.

Organic Chemistry.—Conference.

Metallurgy.—Metallurgical Processes. Furnaces. Refractory Building Materials. Combustion. Natural and Artificial Fuels. Metallurgy of Iron.

German.—Systematic Readings. Compositions in German. Lectures on German Literature. Or *French.*—Systematic Readings. Compositions. Lectures on French Literature. Conversation Class in both languages optional.

Mineralogy.—Descriptive Mineralogy, with Practical Exercises in the Determination of Minerals. E. S. Dana.

Essays and Original Orations.

Gymnasium.

Senior Class.

First Term.

Metallurgy.—Of Copper, Lead, Silver, Gold, Platinum, Mercury, Tin, Zinc, Nickel, Cobalt, Arsenic, Antimony and Bismuth.

Assaying.—Including the Assay by the dry methods of Gold, Silver, Antimony, Lead, Iron and Tin ores, Coal, Gold and Silver Bullion and rich Lead. Ricketts.

Organic Chemistry.—Laboratory.

Organic Chemistry.—Conference.

Geology.—Lithology, with Practical Exercises in Determining Rocks.

Gymnasium.

Second Term.

Industrial Chemistry.—Lectures and Laboratory.

Agricultural Chemistry.—Lectures.

Sanitary Chemistry.—Laboratory.

Geology.—Historic and Dynamic Geology. Lectures. Le Conte.

Christian Evidences.—Lectures.

Lectures on American and English Literature.

Preparation of Thesis.

Gymnasium.

The Course in Electricity.

This course was established to answer the growing demand for more extensive and thorough knowledge of the subject of Electricity and its application to Machines, Telegraphy, Electric Lighting, etc.

Instead of an extended department of Electrical Engineering, including full courses of Mathematics, Mechanics, Chemistry, etc., and extending over four years, it was thought best to offer for the present a course, occupying not more than one year and presenting very fully the purely electrical portion of an Electrical Engineering course, with only such outside branches as are absolutely necessary for the proper understanding of this single subject.

First Term.

Magnetism and Electricity.—Text-book (S. P. Thompson) and Lectures. Electrical Arithmetic (Day's).

Mechanics.—(Laboratory work.) Precise measurements with beam-compass, spherometer, cathetometer, micrometers, etc. Testing balances. Specific gravities of solids, liquids and gases by all known methods, with balances, hydrometers, comparison of densities and cathetometer, etc.; with corrections for temperature and buoyancy of air, etc. Laws of gravity, with determinations by Atwood's machine, pendulum, etc. Elasticity; Young's modulus by stretching, flexure and torsions, tenacity of wires, superficial tension of capillary tubes of different liquids. Work with mercurial and aneroid barometers, with all corrections and reductions, to freezing point, sea level, etc.; measurement of heights and levelling roads.

Magnetism and Static Electricity.—(Laboratory work.) Making and testing permanent magnets. Verification of laws by Coulomb's torsion balance. Measurements of portative force, strength of pole, effects of heating, percussion, etc. Study of the distribution of magnetism and drawing magnetic curves. Investigation of local attraction, variation of magnetic needle and intensity of the earth's magnetism.

Construction of electroscopes, condensers. Determination of electrical character of many substances. Verification of laws of electrical attraction and repulsion. Measure-

ments of conductivity, electric density and capacity. Study of laws of Static induction, specific inductive capacity, etc., and of condensers. Analysis of machines, electrophorus, plate glass machines, Holtz's, etc.

Meteorology.—Text-book (Loomis) and practice. Observations for one month as taken in the U. S. Signal Service stations; with all the usual corrections and reductions construction of charts; mapping curves, etc.

Drawing.—Elementary Projections. Freehand Drawing.

Second Term.

Dynamic Machinery.—Text-book (S. P. Thompson) and lectures.

Electric Lighting.—Text-book (Du Moncel) and lectures.

Telegraph.—Lectures.

Sound, Heat and Light.—(Laboratory work.) Determination of number of vibrations of notes with Siren, comparison of pitch of tuning forks. Determination of velocity of sound in air. Verification of laws of vibrations of strings. Determination of absolute pitch of notes by the monochord and of wave lengths of notes by sensitive flames. Making and testing thermometers; determinations of freezing and boiling points of different substances; of coefficients of expansion of solids, liquids and gases; of specific heat of bodies by the known methods and of latent heat of fusion and vaporization. Humidity by various methods. Verification of the laws of light. Photometry; testing intensities of lights with Bunsen's, Rumford's, Foucault's and daylight photometers. Tests of absorptive power of different substances. Index of Refraction of unknown substances by various methods. Measurements of focal lengths of lenses and mirrors. Construction of optical instruments, finding magnifying power, etc. Spectroscopic work; mapping Frauenhofer lines; identification of unknown substances in solution; absorption spectra (solids and liquids); comparison of spectra; mapping of spectra. Interference. Diffraction spectra. Construction of polariscopes; laws of polarization by reflection and double refraction. Study of uniaxial and biaxial crystals.

Dynamic Electricity.—(Laboratory work.) Setting up, use and care of all batteries in common use, Grove's, Daniel's, LeClanchè's, Bichromate, Bunsen's, Smee's, Gravity, etc.; Secondary batteries, Plantè's, Faure's. Construction of electro-magnets; tests for portative force and strength of pole under varying conditions of current strength, size of wire, number of coils, length and diameter of cores, etc. Laws of currents. Electro-Dynamics. Testing thermo-electric batteries, Noë's and Clamond's. Electrolysis, electrotyping and electroplating. Making induction coils; testing different orders of induced currents and extra currents. Similar study of magnetic induction. Analyses and tests of electro-magnetic and dynamic machines. Diamagnetism.

Electrical Measurements.—(Labratory work.) Practical construction of instruments; sine, tangent and differential galvanometers, ammeters, voltameters, resistance coils, commutators, etc. Verification of Ohm's laws under varying conditions of electromotive force and external and internal resistance. Measurement of resistance of solid and liquid conductors in single and divided circuits; and of effects of change in temperature; of internal resistance, electromotive force and current strength of voltaic batteries. Measurements of quantitative laws of electrolysis, comparisons of voltameters and galvanometers. Testing electric lights, measurements of potential and incandescent lamps; their resistance, hot and cold and amount of heat units given off. Photometric measurements of incandescent lamps; Swan's, Lane-Fox's, Maxim's, Edison's, etc.; and of arc lamps, Weston's, Thompson-Houston's, etc. Spectroscopic study of all these lights and mapping their spectra.

Photographing the lines of force of the field magnets of various types and dynamos. Measurements of current strength, difference of potential and resistance of dynamos. Study of different plants and systems of dynamos by visits to manufactories and working systems.

Telegraphic measurements; measuring and testing lines for conductivity, insulation, location of faults, etc.

Physical Culture.

The Gymnasium is open morning, afternoon and evening, in all, 45 hours a week. Exercises in it is required of all students who are fitted to take it. Class drill with the Instructor and Individual exercise are prescribed.

Diplomas and Certificates.

The Diploma is given only to those who have passed all the examinations in a regular course and is signed by the President and Secretary of the Board of Trustees and by the Faculty of the University. For all the partial courses, a certificate, signed by the President and the Secretary of the Faculty, is given, showing what the student has accomplished.

The University Library.

The Library building was erected by the Founder of the University in 1877, at a cost of One Hundred Thousand Dollars, as a memorial of his daughter, Mrs. Lucy Packer Linderman, and during the same year more than Twenty Thousand Dollars were contributed by her family and friends, as a memorial fund for the purchase of books. By the will of the Founder of the University a fund of $500,000 has been given for the permanent endowment of the Library.

The building is semi-circular in plan, with a handsome façade in the Venetian style of architecture. It is constructed of Potsdam sandstone with granite ornamentation. In the interior, the centre is occupied as a reading space, fifty by forty feet, from which radiate the book cases, extending from floor to ceiling; two galleries affording access to the upper cases. Shelf room is now provided for one hundred and sixty thousand volumes. The building is thoroughly fireproof, well lighted, and heated by steam.

Sixty-seven thousand volumes are now upon the shelves, including many extremely valuable works. The list of periodicals numbers about one hundred and twenty-five, embracing as far as possible all departments of knowledge.

The Library is conducted strictly for consultation, and is open to the use of the public; both of which conditions are in accord with the terms of the gift.

Observatory.

By the liberality of Robert H. Sayre, Esq., one of the Trustees of the University, an Astronomical Observatory was erected on the University grounds, and placed under the charge of the Professor of Mathematics and Astronomy.

In the dome of the Observatory is mounted an Equatorial Telescope, of six inches aperture, by Alvin Clark & Sons. The west wing contains a superior Sidereal Clock, by Wm. Bond & Sons; a Zenith Telescope, by Blunt, and a Field Transit, by Stackpole. There is also a Prismatic Sextant, by Pistor & Martins.

Students in Practical Astronomy receive instruction in the use of the instruments and in actual observation.

The grounds upon which the Observatory stands, consisting of seven acres of land adjoining the original grant, was presented to the University by Charles Brodhead, Esq., of Bethlehem.

An advanced course in Astronomy and the higher Analysis has been established, requiring two years for its completion. It is adapted to the attainments of the graduates of this University, but is open to any one who may be prepared to pursue it.

This course embraces the following subjects:

First Year.—Spherical Astronomy. Theory of Instruments. Method of Least Squares. Numerical Calculus.

Second Year.—Celestial Mechanics. Interpolation and Quadrature. Computation of Orbits and Perturbations.

During the entire course the student will have ample opportunity to familiarize himself with the practical work of the Observatory and Computing Room.

The University Museum.

In addition to the large collection illustrating all branches of Industrial Chemistry, the Museum includes collections in Metallurgy, Geology, Zoology and Archæology.

The Metallurgical Cabinet already includes specimens illustrating the various processes for obtaining the more common metals.

The Zoological Cabinet includes the Werner collection of nearly all the types of American birds with their nests and eggs, and the Packer collection of recent shells.

The Geological Cabinet numbers over ten thousand specimens and includes the Palæontological, Mineralogical, Petrographic and Economic collections. The former contains good specimens of nearly all the common genera. The Mineralogical division includes the Keim and Rœpper collections—the latter being especially complete and valuable from a crystallographic standpoint. The Petrographic division numbers several thousand specimens and besides including numerous varieties of nearly all the rocks of the globe, contains a duplicate set from the collection of the Second Geological Survey of this State. The Economic division was formed and donated by Dr. James P. Kimball, Director of the Mint, and formerly Professor of Economic Geology.

The Cummings Archælogical Cabinet numbers three thousand specimens and includes Dr. Stubbs' collection of Indian relics, weapons and utensils.

Theses.

Theses on the following subjects were prepared by the graduating class of 1887 :—

"A Theoretical and Practical Investigation of Railroad Rail-Joints."

"An Examination of the Zinc Blende from Friedensville, Pa."

"Design of a Boiler for a Passenger Locomotive."

"Plan and Estimate for a Water Supply for the Lehigh University."

"Comparison of Two Types of Steam Fire-Engines."

"Ruskin on the Labor Question."

"Steam Heating."

"The Three-Point Problem and its Application to the Finding of a Lost Station."

"Friction."

"Design of Pumping Engines for the City of Scranton."

"Discussion of the Errors in Precise Levelling."

"Discussion of the Precision of the Sægmüller Solar Attachment."

"Design of a Direct-Acting Steam Pump."

"The Drainage of the Borough of Bethlehem, with a Plan for the Improvement of the Streets."

"Review of the New Sewage System of the City of Chicago."

"Design of a Roof Truss of 100 Feet Span."

"Design and Estimate of Cost for an Impounding Reservoir on Mill Run, near Altoona, Pa."

"The Fireless Locomotive."

"Plan and Estimate for a Suburban Railroad for Washington, D.C."

"Design and Estimate for a Cable Railway for Bethlehem."

"An Investigation of the Easton and South Easton Suspension Foot-Bridge."

"An Experimental Investigation of the Stiffening Girders of Suspension Bridges."

"The Practical Determination of an Azimuth."

"Design of a Machine for Binding Books."

"On the Solubility of the Oxides of the Common Metals in Water Glass."

"The Flow of Water over Weirs, with a Discussion of the Experiments made by the Class of 1887 on the Weir in the Hydraulic Laboratory of Lehigh University."

"The Geology of the Salem Coal Basin, Shickshinny, Pa."

"Discussion of Recent Experiments on Friction."

"The Preparation of Anthracite Coal, with a Review of the Deringer Breaker."

"Blow Holes in Bessemer Steel Castings."

"Review of the Water Supply of Allentown, Pa."

"Design of a Boring Machine for Large Cylinders."

The following list of the Alumni of the Lehigh University shows the positions gained by them on the line of their professional training :—

Charles E. Ronaldson, M. E., Engineer Siemen's Regenerative Gas Furnace, Philadelphia.

Miles Rock, C.E., Chief of the Boundary Commission of Guatemala with Mexico San José, Guatemala.

Harry R. Price, C.E., Mining Engineer, Pottsville, Pa.

John M. Thome, C. E., Director National Astronomical Observatory, Cordova, Argentine Republic.

J. N. Barr, M.E., Mechanical Engineer, Chicago, Milwaukee & St. Paul R.R.

George P. Bland, C.E., Civil Engineer, Philadelphia.

Henry St. L. Coppée, C.E., U.S. Assistant Engineer, Vicksburg Harbor, Vicksburg, Miss.

F. R. C. Degenhart, A.C., Chemist, Havemeyer Sugar Refining Co., New York.

Harvey S. Houskeeper, B.A., Instructor in Physics, Lehigh University.

L. E. Klotz, C.E., Contractor for Crellin & Klotz, Mauch Chunk, Pa.

O. M. Lance, A.C., Superintendent Plymouth Water and Gas Companies, Luzerne Co., Pa.

R. Floresta de Miranda, C. E., Division Engineer, San Francisco R. R., Province of Bahia, Brazil.

James S. Polhemus, C.E., U.S. Assistant Engineer, Harbor Improvements, Newport, Benton Co., Oregon.

J. P. S. Lawrance, M. E., Passed Assistant Engineer U. S. Navy, Office of Naval Intelligence, Bureau of Navigation, Navy Department, Washington, D.C.

C. W. Haines, A. M., (Haverford,) C. E., Ass't Astronomer, National Observatory, Cordova, Argentine Republic.

W. D. Hartshorne, C.E., Superintendent Arlington Mills, Lawrence, Mass.

W. M. Rees, C.E., Engineer Corps, Government Improvement of Mississippi River, Memphis, Tenn.

Charles J. Bechdolt, C. E., Supervisor, Monongahela Division P. R. R., Monongahela, Pa.

Antonio M. Cañadas, A.C., Chemist, Loja, Ecuador.

W. A. Lathrop, C. E., Superintendent Snow Shoe Division, L. V. Coal Co., Snow Shoe, Pa.

A. E. Meaker, C. E., Instructor in Mathematics, Lehigh University, Bethlehem, Pa.

Francis S. Pecke, C. E., Contractor's Engineer and Superintendent, B. & O. R. R., Darley, Delaware Co., Pa.

E. H. Williams, Jr., B. A., (Yale) A. C., E. M., Professor of Mining and Geology, Lehigh University, Bethlehem, Pa.

J. D. Carson, C. E., General Manager, C. & W. I. R. R. Co., and Belt R. R. Co., Chicago, Ill.

William Griffith, C.E., Assistant Geologist, Geological Survey of Pennsylvania, Room 45, Coal Exchange, Scranton, Pa.

C. W. MacFarlane, C. E. Superintendent Foundry, William Sellers & Co., Philadelphia.

R. W. Mahon, C.E., Ph.D., Chemical Manufacturer, 110 Arch Street, Camden, N.J.

J. J. de Malcher, M.E., Naval Officer, Custom House, Para, Brazil.

Col. W. P. Rice, C.E., U.S. Assistant Engineer, Cleveland, Ohio.

Henry Richards, E. M., Mining Engineer, Trabo Mine, Dover, N.J.

L. W. Richards, M. E., Superintendent of Steel Department, Chester Rolling Mills, Thurlow, Pa.

Henry S. Jacoby, C.E., Instructor in Civil Engineering, Lehigh University, Bethlehem, Pa.

James F. Marstellar, C. E., Assistant Superintendent L. V. Coal Co., Snow Shoe Division, Snow Shoe, Pa.

Seizo Miyahara, C.E., Interior Department, Tokio, Japan.

Lewis T. Wolle, C. E., Assistant to Chief Engineer Union Pacific R. W., Omaha, Neb.

Frank P. Howe, B.A., (Brown) E.M., President and General Manager North Branch Steel Co., Treasurer Mahoning Rolling Mill Co., Danville, Pa.

Benjamin B. Nostrand, Jr., M. E., U. S. Electric Lighting Co., New York.

Milnor P. Paret, C.E., Division Engineer, C. & R. R. R., Oakley, O.

H. F. J. Porter, M.E., Superintendent, Columbia College, New York.

Robert H. Reed, B.A., Room 91, Division Electricity, U.S. Patent Office, Washington, D.C.

Henry C. Wilson, C. E., Chief Clerk and Consulting Engineer, U. S. Eng. Office, Custom House, St. Louis, Mo.

J. S. Cunnigham, M.E., Superintendent for Receiver Everett Iron Co., Everett, Pa.

J. H. Paddock, M.E., Chief Engineer, H. C. Frick Coke Co., Scottdale, Pa.

F. W. Sargent, C. E., Engineer of Tests, Chicago, Burlington & Quincy R. R., Aurora, Ill.

R. H. Tucker, Jr., C.E., Assistant Astronomer, National Astronomical Observatory, Cordova, Argentine Republic.

Abram Bruner, E.M., Assistant Engineer, Superintendent's Office, Eastern Division, Pa. Co., Allegheny, Pa.

Murray Morris Duncan, A. C., E. M., Superintendent Roane Iron Co., Rockwood, Tenn.

John Tinsley Jeter, E. M., Mining Engineer, L.V. Coal Co., Wilkes-Barre, Pa

Charles Francis King, A.C., Chemist, Penn. Steel Co., Steelton, Pa.

Fred Putnam Spalding, C. E., Instructor in Civil Engineering, Lehigh University, Bethlehem, Pa.

Benjamin Russell Van Kirk, M. E., Draftsman, Baldwin Locomotive Works, Philadelphia, Pa.

William Simon Cranz, A.C., Analytical Chemist, Tuscon, Arizona.

Thomas Morgan Eynon, Jr., M. E., Assistant Superintendent Diamond Slate Co., Wilmington, Del.

Benjamin Franklin Haldeman, E.M. Chemist, Cambria Iron Co., Johnstown, Pa.

Louis Oscar Emmerich, E.M., Resident Engineer E. Sugarloaf Collieries, Stockton, Pa.

Elmer Henry Lawall, C.E., Engineer, Beaver Brook Estate, Audenried, Pa.

Robert Thomas Morrow, Jr., C. E., Supervisor and Assistant Train Master, Lewisburg & Tyrone R.R., a Division of the Pennsylvania R.R., Lewisburg, Pa.

Eugene Rickseeker, C.E., Topographer in charge U. S. Geological Survey, Washington, D.C.

Francis Wharton Dalrymple, C.E., Division Engineer, Delaware Division N.Y.L.E. & W. R. R., Port Jervis, N.Y.

George Francis Duck, E.M., Instructor in Mining, Lehigh University, Bethlehem, Pa.

Alfred Edmund Forstall, M. E., Assistant to General Manager Chicago Gas Light and Coke Co., Chicago, Ill.

George Gowen Hood, C.E,, Engineer, Cambria Iron Co., Atkins Tank, Smyth Co., Va.

Julian de Bruyn Kops, B.E., C.E., Assistant City Surveyor, Savannah, Ga.

Preston Albert Lambert, B.A., Instructor in Mathematics, Lehigh University.

Edwin Francis Miller, M. E., Instructor in Mechanical Engineering, Lehigh University, Bethlehem, Pa.

Thomas Nicholson, Jr., M. E., Engineer Johnson Frog and Switch Co., Chester, Pa.

George Spencer Patterson, E. M., Engineer, Union Improvement Co., Mahanoy City, Pa.

Henry Allebach Porterfield, E. M., Assistant Engineer of Tests, Cambria Iron Co., Johnstown, Pa.

Jesse Wilfred Reno, E.M., Mining Engineer and Metallurgist, Boston, Mass.

Charles Loomis Rogers, M.E., Engineer, N. Y. C. & H. R R. R.

Robert Grier Cooke, B. A., Principal Preparatory Class, for Lehigh University, Moravian Parochial School, Bethlehem, Pa.

Henry Bowman Douglass, E. M., Assistant Superintendent, Roane Iron Co., Rockwood, Tenn.

John Andrew Jardine, E.M., Assistant Superintendent, in charge of Blast Furnaces, Monto Alto Iron Co., Monto Alto, Franklin Co., Pa.

James Warner Kellogg, M. E., Engineer's Office, Kansas City, Springfield and Memphis R.R. Co., Springfield, Mo.

Joseph Franklin Merkle, C.E., Assistant to Geologist and Engineer of the Fuel Gas and Elec. Eng. Co., (Limited), Pittsburgh, Pa.

Harry Krider Myers, C. E., Resident Engineer and Superintendent, Houtz Heirs' Estate, Houtzdale, Pa.

Richard Washington Walker, C.E., Assistant Engineer Guatemala Boundary, Survey with Mexico, Guatemala, C.A.

James Angus Watson, C.E., Assistant Supervisor Northern Central Railway, Union Station, Baltimore, Md.

Irving Andrew Heikes, E.M., Chemist and Mining Engineer, Magnetic Iron Ore Co., Carthage. N.Y.

David Kirk Nicholson, M.E., Asst. Supt. of the Rail, Universal and Blooming Mills, Penna. Steel Co., Steelton, Pa.

Fayette Brown Petersen, C.E., Instructor in Metallurgy, Lehigh University.

Clarence Moncure Tolman, M. E., Engineer, Armington & Sims' Engine Co., 38 Carpenter Street, Providence, R.I.

Frederick William Fink, C. E., Engineering Department, Union Pacific Railway, Omaha, Neb.

Robert Caldwell Gotwald, C.E., Missouri Pacific Railroad, Nebraska City, Mo.

William Anthony Lydon, B. M., Assistant Engineer Department of Public Works, Chicago, Ill.

Joseph William Richards, A.C., Instructor Lehigh University, Bethlehem, Pa.

George Mann Richardson, A.C., Johns Hopkins University, Baltimore, Md.

George Arthur Ruddle, B.Ph., Instructor, Selwyn Hall, Reading, Pa.

John Selmar Siebert, C. E., Assistant Engineers' Office, Pennsylvania Railroad Co. Pittsburgh, Pa.

John Henry Spengler, C. E., Construction Department, Chicago, Sante Fé & California Railway Co., 721 Rialto Building, Chicago, Ill.

Theodore Stevens, B. M., Assistant Chemist, Cowles Electric Smelting & Aluminum Co., Lockport, N.Y.

Charles Austin Buck, A.C., Assistant Chemist, Bethlehem Iron Co., South Bethlehem, Pa.

Benjamin Amos Cunningham, C. E., Chief Engineer's Office, L. V. R. R., Mauch Chunk, Pa.

Alfred Doolittle, B. A., Instructor in Ulrich's Preparatory School for Lehigh University, Bethlehem, Pa.

John Myers Howard, M.E., care Assistant Engineer, P.R.R., Harrisburg, Pa.

Evan Turner Reisler, C.E., Engineer Corps, Delaware Division, N.Y., L.E. & W.R. R. Co., Port Jarvis, N.Y.

Edward Power Van Kirk, E.M., Johns Hopkins University, Baltimore, Md.

The number of Graduates is 252, of whom there are 23 who have taken the Degree of B.A. ; 7 of B.Ph. ; 99 of C.E. ; 51 of M.E. ; 24 of E.M. ; 25 of A.C. ; 13 of B. M. ; 8 of B.S. ; 2 who have taken the two degrees of A.C. and E.M. ; 1 who has taken both B.S. and C.E. ; 5 who have taken B.M. and E.M. ; 1 who has taken C. E. and E. M. ; and 1 who has taken B.M., A.C., and E.M.

COLUMBIA COLLEGE (SCHOOL OF MINES).

The Faculty of the School of Mines of Columbia College, New York City, consists of fourteen professors and thirty instructors, as follows :—

Frederick A. P. Barnard, S.T.D.. LL.D., L.H.D., D.C.L., President.

Professors.

Charles F. Chandler, Ph.D., M.D., LL.D., Chemistry. Dean of the Faculty.
William G. Peck, Ph.D., LL.D., Mechanics.
William P. Trowbridge, Ph.D., LL.D., Engineering.
William R. Ware, B.S., Architecture.
John K. Rees, A.M., E.M., Geodesy and Practical Astronomy. Director of the Observatory.
Elwyn Waller, A.M., E.M., Ph.D., Analytical Chemistry.
Henry S. Munroe, E.M., Ph.D., Surveying and Practical Mining (adjunct).
Frederick R. Hutton, C.E., Ph.D., Mechanical Engineering (adjunct).
Thomas Egleston, E.M., Ph.D., LL.D., Mineralogy and Metallurgy.
J. Howard Van Amringe, A.M., Ph.D., Mathematics.
Ogden N. Rood, A.M., Physics.
John S. Newberry, M.D., LL.D., Geology and Palæontology.
Pierre DePeyster Ricketts, E.M., Ph.D., Assaying.
Jasper T. Goodwin, A.M., LL.B., Mathematics (adjunct).

Instructors.

John S. Billings, M.D., Lecturer on Hygiene and Sanitary Science.
James S. C. Wells, Ph.D., Instructor in Qualitative Analysis.
Alexis A. Julien, A.M., Ph.D., Instructor in Biology and Miscroscopy.
Alfred J. Moses, E.M., Instructor in Mineralogy and Metallurgy.
James L. Greenleaf, C.E., Instructor in Engineering and Drawing.
Charles E. Colby, E.M., C.E., Instructor in Organic Chemistry.
Ferdinand G. Weichmann, Ph.D., Instructor in Chemical Philosophy and Chemical Physics.
Nathaniel L. Britton, E.M., Ph.D., Instructor in Botany.
Alfred D. F. Hamlin, M.A., Instructor in Architecture.
Louis H. Laudy, Ph.D., Assistant in General Chemistry. Assistant Instructor in Applied Chemistry.
William W. Share, Ph.D., Assistant in Physics.
Ralph E. Mayer, C.E., Assistant in Drawing.
Ira H. Woolson, E.M., Assistant in Drawing.
Charles B. Laraway, Assistant in Natural History.
Henry C. Bowen, Fellow in Chemistry. Assistant Instructor in Quantitative Analysis.
Herman T. Vulté, Ph.D., Fellow in Chemistry. Assistant Instructor in Qualitative Analysis.
Thomas Ewing, Jr., A.M., Fellow in Physics.
Joseph Struthers, Jr., Ph.B., Fellow in Mineralogy.
Frederick J. H. Merrill, Ph.B., Fellow in Geology.
William H. Stuart, C.E., Fellow in Engineering, and Honorary Fellow in Mathematics.
John I. Northrop, E.M., Fellow in Geology.
George H. Gilman, A.B., Fellow in Physics.

Frank Dempster Sherman, Ph.B., Fellow in Architecture.
Lea McI Luquer, C.E., Fellow in Mineralogy.
Francis M. Simonds, E.M., Fellow in Chemistry. Assistant Instructor in Assaying.
Elihu D. Church, Jr., E.M., Honorary Fellow in Qualitative Analysis.
Charles E. Pellew, E.M., Honorary Fellow in Sanitary Engineering and Bacteriology.
Roland G. Rood, Ph.B., Honorary Fellow in Physics.
Lewis H. Rutherford, E.M., Honorary Fellow in Practical Mining.
Frederic W. Tower, E.M., Honorary Fellow in Engineering
George F. Fisher, Registrar.
Robert M. Ricketts, Assistant Registrar.

COURSES OF STUDY, ADMISSION, ETC.

The system of instruction includes seven parallel courses of study, viz :

I. Mining Engineering.
II. Civil Engineering.
III. Metallurgy.
IV. Geology and Palæontology.
V. Analytical and Applied Chemistry.
VI. Architecture.
VII. Sanitary Engineering.

At the beginning of the first year, each student must elect which of the seven courses he intends to pursue, and must thenceforth abide by his election unless permitted by the faculty to make a change.

No student is allowed to pursue more than one course at a time.

The plan of instruction includes lectures and recitations in the several departments of study; practice in the chemical, mineralogical, blowpipe, and metallurgical laboratories; field and underground surveying; practice and study in mines, mills, machine shops, and foundries; projects, estimates, and drawings for the working of mines and for the construction of metallurgical, chemical, and other works; reports on mines, industrial establishments, and field geology.

The course of instruction occupies four years.

There is an advanced course for graduates.

The method of instruction is such that every pupil may acquire a thorough theoretical knowledge of each branch, of which he is required to give evidence, at the close of the session, by writen and oral examinations. At the commencement of the following year he is required to show, from reports of works visited, that he understands not only the theoretical principles of the subjects treated, but also their practical application—a point that is insisted on with great rigor.

Admission to the Regular Courses.

Candidates for admission to the first class, at its formation, must be of the age of *eighteen years*, complete ; and for admission to advanced standing, there will be required a corresponding increase of age.

Candidates for the first class must pass a satisfactory examination :—

In *arithmetic*, including the metric system of weights and measures.

In *geometry*, on the nine books of Davies' Legendre.

In *algebra*, on the first ten chapters of Peck's Manual of Algebra.

In *physics*, on the equivalent of Ganot's smaller treatise (Peck's Ganot's Natural Philosophy).

In *chemistry* of the non-metallic elements, on the equivalent to what is contained between pages 131 and 274 in Fownes' Manual of Chemistry, 12th edition.

In *German*, on the general principles of the German grammar, including an ability to read Das Buch der Natur, Physik, Chemie, by F. Schoedler.

In *French*, on the general principles of the French grammar, including an ability to read Simples Lectures sur les Sciences, by M. Garrigues ; revised by B. de Movel, Paris.

In *English grammar*, on the equivalent of Quackenbos's English grammar.

In *composition and rhetoric*, on the equivalent of Quackenbos's Course of Composition and Rhetoric.

In *history*, on the equivalent of Thompson's History of England and Doyle's History of the United States as contained in Freeman's Historical Course for schools.

In *physical geography*, on the equivalent of Appleton's or Guyot's Physical Geography.

In *free-hand drawing*, including the ability to sketch, both in outline and with proper shading, ordinary objects such as a tree, a house, a simple piece of machinery, a piece of flat ornament from a copy, a group of geometrical solids, etc.

In *book-keeping*, on a knowledge of double entry so far as relates to the keeping of ordinary accounts in cash-book, day-book, and ledger, and the making out of corresponding balance sheets.

An applicant may, at the appointed entrance examinations of one year, be examined in portions of the above subjects that are complete in themselves, *e.g.*, arithmetic, algebra or, geometry, English grammar, composition and rhetoric, history, etc., and finish his examinations in the requirements for admission at the entrance examinations of the year following.

Graduates of colleges presenting a diploma for the bachelor's degree will not be held to examinations for admission upon arithmetic, algebra, geometry, trigonometry, chemistry, English grammar, composition and rhetoric, American and English history, and physical geography.

Graduates and students of colleges and schools of science, who shall have completed so much of the course as shall be equivalent to the requirements for admission, may be admitted at the beginning of the second year, or earlier, without examination, on presenting diplomas or certificates of good standing and honorable dismissal satisfactory to the examining officers.

Candidates for advanced standing must pass a satisfactory examination upon the studies named above, and also upon those pursued by the class which they purpose to enter.

Candidates for admission after the opening of a term will be required to pass satisfactory examinations on the part of the course already gone over by the class for which they are applicants.

No candidates are admitted later in the course than the beginning of the third year.

Fees and Necessary Expenses.

1. Each student must pay a fee of five dollars before matriculation in each year, and such fee must be paid by the applicant for admissson before examination ; and in case the examination is held at a time not appointed in previous public announcements, the fee required is ten dollars.

In the case of an applicant who completes his examination for admission at the appointed entrance examinations of two successive years, but one fee of five dollars is required.

2. The annual tuition fee is *two hundred dollars*, payable one half on the first day of each session.

3. Every student admitted to an extra examination, in anticipation of the time regularly appointed, or in consequence of failure to attend or to perform satisfactorily at any intermediate or concluding annual examination throughout the course, is required to pay a fee of five dollars before being admitted to such examination.

4. Every candidate for the degree of engineer of mines, or for the degree of civil engineer, or metallurgical engineer, or bachelor of philosophy, or bachelor of architecture,

is required to pay a fee of twenty-five dollars before being admitted to the final examination.

5. Every candidate for the degree of doctor of philosophy is required to pay a fee of thirty-five dollars before entering the examination for such degree.

(4 and 5 are not applicable to students who entered the school prior to January 1, 1883, but such students are held to the payment of five dollars for a diploma.)

6. The necessary expenses of a student are—

Board, including room-rent, fire and light, and washing, from $6.50 to $10 per week.

Matriculation fee, $5.

Annual tuition fees, $200.

Text books about $15 for the first class, $30 for the second class, $50 for the third class, and $20 for the fourth class.

Drawing materials $15 to $25 for each of the first and second classes, and $5 to $10 for each of the others.

Laboratory apparatus (for students who take laboratory courses), $30 to $60 for each of the four years.

During the vacation at the close of the second year, travelling and board for summer class in field surveying (for students in the courses of engineering, metallurgy, and geology), $60 to $80.

During the vacation at the close of the third year, travelling and board for summer class in practical mining (for students in the courses of mining engineering and metallurgy), $75 to $100, and for summer class in practical geodesy (for students in the course of civil engineering), $60 to $80.

Graduation (final examination), $25.

7. The fees required for graduates of the school, attending the school, but not candidates for a degree, are as follows:

1. Matriculation fee	$5
2. Full fee, entitling the student to all the privileges of the school, per annum	150
3. For the use of the cabinets	25
4. For attendance on lecture-room and other special instruction, per annum for each hour per week of such instruction	25
Or for any number of hours per week as above specified	150
5. For the use of the drawing academy	25
6. For the use of the laboratories or either of them	50

Should the amount of fees, exclusive of the matriculation fee, payable by any student not exceed $100, the entire amount is payable at the beginning of the academic year, or at the matriculation of the student. Should the amount exceed $100, payment is required in two equal instalments, one at the beginning of each session of the academic year.

Graduates who are candidates for degrees must pay $150, irrespective of the number of hours of weekly attendance, and for examination,

For degree of doctor of philosophy	$35
For other degrees	25

In the summer school of chemistry the fees for instruction, use of laboratories and chemicals, is $50 for the three months, or $20 for each month or part of a month.

Free Tuition.

It is the desire of the trustees to extend, as widely as possible, the educational advantages of the college to deserving young men. Free tuition is therefore offered to such, under the conditions specified below.

Candidates for free tuition must fulfil the following conditions :

1. The applicant must present a certificate from some person or persons of good repute, stating—

That his circumstances are such that he cannot pay the tuition fee ;

That he is of good moral character and studious habits ;

That the writer is not a relative.

A proper blank will be furnished on application to the registrar.

2. He must exhibit a proficiency in every subject of examination for admission expressed by the number 6 of a scale of which 10 is the maximum. (Conditioned students will not receive free tuition.)

3. He must maintain, subsequent to his admission, a standing in scholarship in every department of study expressed by the number 7, or an average standing in all departments expressed by the number 8, of a similar scale, with no deficiency in any department, failing which he will forfeit his privilege. He will also forfeit his privilege should he be found deficient in any department at the end of the year.

4. Free students are not exempt from the payment of the fees for matriculation, for extra examinations, and for graduation.

This provision for free tuition, does not apply to special students in the summer school in chemistry.

Apparatus Supplies.

I. Students may purchase apparatus of any of the dealers in the city.

II. To avoid inconvenience and expense to the students, and to secure a proper selection, the school undertakes, at considerable trouble and expense, to lend apparatus on the following conditions :

1. Each student engaged in laboratory work must make a deposit of $40 with the registrar, which deposit will be credited to him on the ledger.

2. Each such student will be entitled, on presenting his receipt at the apparatus room, to draw the regular set of apparatus for qualitative, quantitative, or organic analysis, for assaying, for miscroscopy, or for bacteriology, according to his deposit, and from time to time to obtain ordinary articles which he may need, and these will be charged to him. At the end of the session he will be credited with those articles which he returns in good order, and the value of those which he has injured or broken will be deducted from his deposit.

3. The apparatus room will be open for issuing apparatus every day at convenient hours.

4. No charge is made for ordinary chemicals.

Excursions.

During the session the students may visit the different machine shops and metallurgical establishments of the city and its environs.

During the vacations following the close of each year memoirs on subjects which will be assigned are required of students as follows :—Of all students at the close of the first year ; of students in the courses of analytical and applied chemistry, and of architecture at the close of the second year ; of students in all courses, except that of metallurgy, at the close of the third year. The time specified for the completion and handing in of engineering memoirs is the second Monday in October in each year ; for other memoirs the specified time is November 1st.

During the vacation following the close of the second year, students in the courses of engineering may join a volunteer class in practical mechanical engineering, under the supervision of the adjunct professor of mechanical engineering.

During the latter part of the vacation at the close of the second year, students in the courses of mining and civil engineering, metallurgy, geology, and sanitary engineering,

are required to join the summer class in surveying, under the direction of the adjunct professor of surveying and practical mining.

During the vacation following the close of the third year, students in the courses of mining engineering and metallurgy are required to visit mines or engage in actual work or study, under the superintendence of the adjunct professor of surveying and practical mining.

During the vacation following the close of the third year, students in the course of civil engineering are required to attend a summer class in geodesy for six weeks. The class is under the supervision of the professor of geodesy and practical astronomy.

Scholastic Year.

The year is divided into two sessions: the first commences on the first Monday in October; the second, on the first or second Thursday of February. The lectures close on the Friday of the fourth week before commencement.

Examinations.

There are two examinations every year, one commencing on the last Monday in January, and the other on the Monday of the third week preceding commencement. The former embraces such subjects only as have been completed during the first session. The latter is the final examination in each department of all the classes fòr the year.

In addition to the examinations above noted, examinations are held monthly, or oftener, in all the classes and in every department for the purpose of ascertaining the proficiency of the students in their respective studies.

Commencement and Vacation.

The annual commencement is held on the second Wednesday in June, on which occasion degrees are publicly conferred.

The summer vacation extends from the day of commencement until the first Monday in October, on which latter day the regular course of study commences.

BY-LAWS.

Entrance Conditions.

1. Students admitted conditionally must satisfy all conditions within two months of the date of their admission, unless the time be extended by vote of the faculty.

2. Students who fail to satisfy their entrance conditions, within the time specified, will be dropped from the roll.

Attendance.

3. Prompt attendance is required upon all the exercises of the school. Each instance of tardiness will be counted as half an absence.

4. Attendance during all the hours specified on the scheme of attendance adopted by the faculty is obligatory.

5. Any student who shall have been absent from more than ten per cent. of the exercises in any subject shall not be entitled to examination in that subject.

6. Any student who, being present at the school, shall absent himself from any exercise, or shall leave the grounds during the hours at which his attendance is due, shall be liable to removal from the roll of his class.

7. Students are required to attend all the exercises and pass all the examinations of the class and course to which they belong, unless specially excused by vote of the faculty.

8. Every student who repeats a year is required to fill up his time either with the studies of the year which he is repeating or with studies of some other year, subject to the approval of the faculty.

9. By special permission of the faculty students may attend exercises not required in the class or course to which they belong, provided that such attendance does not interfere with the required exercises of their class and course. Such students are held to the same rules of attendance and examination in the extra studies as in the required studies of their class and course.

10. Students who obtain, on examination, a mark of *eight* or more in any subject may be excused from attendance upon the exercises in that subject. This rule to apply to new students and also to those who repeat the studies of any year. Reports of such standing must be filed with the dean of the faculty who alone is authorized to excuse students from attendance.

11. Any student who shall have passed a satisfactory examination in the School of Arts of Columbia College, in any study forming a part of the regular course of the School of Mines, will not be required to pursue that study in the school.

Examinations.

12. Examinations will be held each month on all subjects taught in the school.

13. Examinations will be held at the end of the first term (semi-annual), or at the end of the year (annual), on all subjects taught in the school.

14. Any student found guilty of fraudulent practices at examination will be summarily dismissed from the school.

15. No student who absents himself from a regular examination is allowed to proceed with his class without a special vote of the faculty.

16. Any student who shall fail to pass in any of his studies at the regular semi-annual or annual examination may present himself for a second examination during the last week of the summer vacation. Failing to pass in this second examination his name will be dropped from the roll of his class ; but he may enter the succeeding class, and present himself with that class for a third examination, failing in which his name will be dropped from the roll of the school.

17. Examinations at times other than here designated are not held except by order of the faculty.

18. No student deficient in mathematics will be permitted to go on with his class.

19. No student pursuing the course of analytical and applied chemistry, deficient in any chemical subject, will be permitted to go on with his class.

20. Students deficient in any other department will not be allowed to go on with their classes without a special vote of the faculty.

21. Deficient students of the second or third year will not be allowed to attend any summer school except the summer school in chemistry, without special permission of the faculty.

22. No student is entitled to a degree until he has passed satisfactory examinations in all the studies of the course in which he desires to graduate.

23. When a student fails to receive his degree with his class, and returns at some latter period to present himself for examination for the same, he will be required to comply with all the requirements at the later date, and the same rule shall apply to students who have received one degree and made application for another.

Standing.

24. Every officer keeps a record of the scholarship of each student.

25. The maximum mark is ten in each department, and six is required to pass a student.

26. Free students must maintain a standing of *seven* in every branch of study, or a general average of *eight* in all branches, with no deficiency in any department, failing which they will forfeit their privileges.

Change of Course.

27. No student shall be permitted to change his course till he has passed in every study of the course which he proposes to leave.

Analyses.

28. Analyses and assays must be made on material supplied or authorized beforehand by the instructor in charge of the laboratory, and the reports must be handed in on the completion of the work.

29. Students pursuing the course of analytical and applied chemistry, and in the course of metallurgy, are required to complete the regular list of analyses within the time allotted, and failing in this, they are not permitted to continue with their classes.

Memoirs.

30. Each student, at the commencement of his second, third, and fourth year, is required to present memoirs on such subjects as may be assigned to him by the faculty, except students in the course of engineering, metallurgy and geology at the end of the second year, and students in the course of metallurgy at the end of the third year.

31. Students of the second, third and fourth classes who fail to hand in the memoirs, drawings, and other summer work required of them under the rules by a specified time, shall not be permitted to hand them in until a year from that specified time, and failing in this latter requirement they shall be dropped from the roll of the class. The time specified for summer memoirs in chemistry, is November 1st of each year, and for other memoirs and summer work the time specified is the second Monday in October.

Under this rule, delinquents in the fourth class cannot graduate with their class at commencement.

Summer Schools.

32. Students are not permitted to attend the summer classes in practical mining and in geodesy unless they have previously completed the course of study in the summer school of surveying.

33. Students who fail to pass satisfactory examinations in qualitative analysis, are required to attend the summer school in chemistry.

34. Students who fail to complete the allotted number of quantitative analyses are required to attend the summer school in chemistry.

Projects and Dissertations.

35. Each student, before graduating, is required to execute projects or dissertations on subjects assigned to him by the faculty. These projects or dissertations must be illustrated by drawings made to a scale.

36. All memoirs, projects, dissertations, and drawings executed in the drawing academy may be retained by the school.

Degrees.

37. Every student who has passed satisfactory examinations in all the studies of a course, and completed the number of projects, dissertations, memoirs, analyses, assays and drawings, is recommended to the Board of Trustees for the degree of engineer of mines civil engineer, metallurgical engineer, or bachelor of philosophy.

38. Graduates of the school, who fulfil the following conditions, are recommended to the trustees for the degree of doctor of philosophy:

(1) Each candidate shall pursue, for the term of at least two academic years, a course of higher study at the school and under the direction of the faculty, in two or more branches of science, and shall pass an improved examination thereon.

(2) He shall also present an acceptable thesis or dissertation embodying the results of such special study, research, or observation, upon a subject previously approved and accepted by the faculty.

In special cases, and for reasons connected with the work which may be satisfactory to the faculty, the faculty of the school is empowered to grant permission to candidates for the degree of doctor of philosophy to perform their work *away* from the school, providing that such candidates matriculate at the school as graduate students, and pay the same fees as are required of resident candidates for the same degree.

Speakers at Commencement.

39. A list of members of the graduating class, from whom a speaker at commencement may be chosen, will be made by the faculty and submitted to the class, who may select as speaker one of the number, subject to the approval of the faculty.

Library.

40. The library is open to students from 8 a. m. to 10 p. m. daily (except Sundays and Good-Friday), throughout the year, including all holidays and vacations.

41. Books taken from the library must be returned within two weeks, or earlier if recalled by the librarian as specially needed.

42. Students must give receipts for books taken, and are responsible for their return in good condition.

The Laboratories and Drawing Academies.

43. No student will be allowed in a laboratory or a drawing academy at a time when his attendance there is not due. During hours assigned for practical work in each of the laboratories and in the drawing academies, the attendance of students will be required. A record of the daily attendance and of the progress of each student will be kept by the officer in charge.

44. The attendance of students of the first and second years in the drawing room at such times as they are not engaged at lectures, between 10 a. m. and 2 p. m., is obligatory for students in engineering and architecture, for such hours and times as may be selected by the professors of engineering and architecture.

Order.

45. Good order and gentlemanly deportment are required of all students, as a condition of attendance upon the exercises of the school.

46. Smoking is prohibited in the college buildings.

SYNOPSIS OF STUDIES.

I.—Course in Mining Engineering.

First Year.

First Session.

Trigonometry and Mensuration, as contained in Davies' Legendre.

Physics—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Sound—lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—The metals. Lectures and recitations; Fownes' Manual of Chemistry.

Qualitative Analysis—Lectures, and Fressenius's Manual of Qualitative Analysis.

Blowpipe analysis—Qualitative; text-book; Platner's Blowpipe Analysis.

Drawing—Free-hand and sketching; lettering, instrumental drawing; projections, intersections, and developments. Text-book: Binn's Orthographic Projection.

Second Session.

Geometrical Conic Sections—Text-book: Peck's Conic Sections.

Algebra—Text-book: Peck's Manual of Algebra.

Graphical Algebra—Text-book: Phillips & Beebe's Graphic Algebra.

Graphics—Descriptive geometry; text-book: Church's Descriptive Geometry.

Physics—Magnetism, electricity, static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics—lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Crystallography—Lectures, conferences, and Egleston's Diagrams of Crystals.

Drawing—Same as first session.

Summer Vacation.

Memoir.

Second Year.

First Session.

Analytical Geometry—Text-book: Peck's Analytical Geometry.

Engineering—Exercises in mathematical problems.

Practical Mining—Excavation, quarrying, drilling and blasting, tunnelling.

Zoology—Lectures, and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics; lectures and laboratory practice.

Applied Chemistry.—Lectures and recitations; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Mineralogy—Lectures and conferences; Egleston's Lectures and Tables of Mineralogy.

Drawing—Topographical drawing; tinting and grading; problems in graphics; scale-construction drawing.

Second Session.

Differential and Integral Calculus—Text-book: Peck's Practical Calculus.

Graphics—Shades and shadows, perspective, isometrical drawing; text-book: Church's Shades and Shadows.

Engineering—Exercises in mathematical problems.

Practical Mining—Excavation, quarrying, drilling and blasting, tunnelling.

Zoology—Lectures, and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—limes, mortars, and cements; building stones: decay and preservation; timber and its preservation; pigments, paints, essential oils, varnishes; glass and ceramics; explosives: gunpowder, gun-cotton, nitro-glycerine; electro-metallurgy, etc.

Mineralogy—Determinative.

Drawing—Construction drawing; mine maps; mine sections.

Summer Vacation.

Optional class in machine shops.

Surveying—Lectures, recitations, and field work; pacing; compass and chain surveys; topographical work; use of solar compass in land and mineral surveys; adjustments and use of transit and wye level for triangulation; traversing, city surveying, and levelling; use of plane table; stratigraphical and magnetic surveys.

Summer class in surveying.

Third Year.

First Session.

Mechanics of solids, including forces, moments, equilibrium, stability, etc, and elementary machines; dynamics, including uniform, varied, rectilineal and curvilinear motion, rotation, vibration, impact, work done, etc.

Physics—Mechanical theory of heat, electricity.

Engineering—general principles relating to materials and structures, physically and mechanically considered.

1. Materials—stone, cements, brick, metals, timber, treated in regard to strength, durability, mode of preparation, defects, tests of quality, and fitness for special uses.

2. Structures—earthwork, execution of earthwork, foundations and supports, superstructure, joints; stability, strength, and stiffness of parts; special rules of construction for masonry of public buildings, bridges, retaining walls, arches, railroads, common roads, and canals.

Physical Properties of Materials—Pig-iron: castings, chilled and malleable; wrought iron; bar, shapes, plate, tube, and wire; steel: ingot metal, castings, shapes and plate; other metals and alloys.

Practical Mining—

1. Boring, earth augers, driven wells, boring with rods and cable tools; upward, inclined, and horizontal boring; diamond drill and its use in prospecting.
2. Shaft sinking, shaft timbering and spiling, boring of shafts, sinking of iron and masonry linings, cribbing, walling, and tubbing.
3. Drifting of adits and levels, timbering and walling in levels and working places.
4. Mining of coal and ores, coal-cutting machines, hand and machine drilling.
5. Handling of coal and ores in working places.
6. Tramming, cars, tracks, locomotive and wire-rope haulage, planes and gravity roads.
7. Accidents to miners, cause and prevention.
8. Organization and administration.
9. Time-books, measurement of contracts, pay-roll, analysis and dissection of accounts and cost sheets.

Assaying and Ore Testing—Lectures, recitations, and practical work.

Metallurgy—General metallurgy; fuel. furnaces, etc.

Geology, Lithological—Rocks and rock masses.

Drawing—General engineering construction; machine construction.

Second Session.

Mechanics of Fluids, including pressure, buoyancy, and specific gravities, motion in pipes and channels, undulation, capillarity, tension and elasticity of gases, the atmosphere, the barometer, barometric formulæ, and hypsometry.

Physics—Electricity, physical optics, and the undulatory theory of light (last two optional).

Engineering—Theory of strains and strength of materials—elasticity, mechanical laws, application of principles of mechanics to beams, girders, and roof trusses under various conditions of loading and supports.

Physical Properties of Materials—Continued from first session.

Practical Mining—

1. Boring, earth augers, driven wells, boring with rods and cable tools; upward, inclined, and horizontal boring; diamond drill and its use in prospecting.
2. Shaft sinking, shaft timbering and spiling, boring of shafts, sinking of iron and masonry linings, cribbing, walling and tubbing.
3. Drifting of adits and levels, timbering and walling in levels and working places.
4. Mining of coal and ores, coal-cutting machines, hand and machine drilling,
5. Handling of coal and ores in working places.
6. Tramming, cars, tracks, locomotive and wire-rope haulage, planes and gravity roads.
7. Accidents to miners, cause and prevention.
8. Organization and administration.
9. Time-books, measurement of contracts, pay-roll, analysis and dissection of accounts and cost sheets.

Metallurgy—Iron and steel.

Geology—Historical, including palæontology, or a systematic review of recent and fossil forms of life.

Drawing—General engineering construction; machine construction.

Summer Vacation.

Summer class in practical mining.

Memoir.

Fourth Year.

(Without distinction of sessions.)

Mining Engineering—

1. Considered in its widest sense as a course of study.
2. Considered in reference to the application of general principles of engineering to the development and working of mines.
3. Classification and nomenclature of mineral deposits; descriptions of lodes or veins, beds, masses, and irregular deposits, with illustrations of the disturbances to which they are subjected, as affecting the work of mining.
4. Graphical representation of deposits; with examples showing modes of occurrence and disturbances.
5. Prospecting or searching for mineral deposits.
6. Exploratory workings.
7. Establishing seats of extraction.
8. Description of typical methods of exploitation as applied to wide veins or lodes, to narrow veins, masses, to beds of various thicknesses and degrees of inclination.
9. General principles relating to subterranean transportation.

10. Methods and machinery employed for extracting minerals from the pits, and for facilitating ascent and descent of workmen.

11. Drainage of mines; theory of infiltrations of water, methods and machinery for draining or freeing mines from water.

12. Ventilation of mines; causes of vitiation of the air of mines; quantities of fresh air required under various circumstances; natural ventilation; mechanical ventilation by fires and by ventilating machinery; distribution of air through galleries and workings.

13. Graphical illustrations of exploratory workings; methods of exploitation; machinery for hoisting, pumping, ventilation and transportation, including the use of steam-engines and pumps, air compressors, air engines, pumping engines, winding engines, centrifugal and other ventilating machines.

Engineering—Theory of strains and strength of materials continued; graphical methods of determining strains, deflection of beams and girders; quantity of material in braced girders under various conditions of loading and supports; angle of economy for bracing; torsion of shafts; crushing and tensile strength of materials; working strains and working load; mode of estimating cost of girder work.

Hydraulic Engineering—Application of principles of mechanics of fluids to determining the discharge of water over weirs or dams; the dimensions of conduit pipes; discharge of canals and rivers; the effect of varying forms and sections of channels and of obstructions to flow; the gauging of streams; retaining walls for reservoirs.

Machinery and Millwork—

1. General theory of motion.
2. Uniform and varied motion.
3. Composition of motions.
4. Instantaneous centre and centroids.
5. Transmissions by rolling and sliding contract, by belting, ropes and chain, by shafting and linkages, by fluids.
6. Engaging and disengaging and reversing gears, and quick-return motions.

Dynamics of Machinery—Forces of nature employed or acting in all machines; dynamical laws, mathematical theorems, measure of forces, work of forces; elementary machines and their combinations; theory of efficiency; theory of fly-wheels, governors and brakes; strength and proportions of parts of machines; dynamometers; prime movers, as driven by animal power, water power, steam power, compressed or heated air, wind power comprising the theory of animal power, theory of water-wheels, overshot wheels, undershot wheels, breast wheels, turbines, re-action wheels, centrifugal pumps; properties and laws of heat as applied to the generation of steam and the construction of boilers; properties of steam and air in their relation to prime movers; mechanical theory of heat applied to steam-engines, hot air engines, compressed air engines; general description of heat engines of various forms; description and theory of ventilating fans or blowers.

Mechanical Engineering—

1. Steam boilers: construction, wear and tear, fittings, setting, testing, care and management, firing, feeding, injectors, pumps, etc.
2. Mechanism of engines—valve gearing, link motions, governors, etc.
3. Management of engines—erecting, emergencies, special types of engines, etc.
4. Proportions of engines, etc.
5. Testing efficiency of engines and boilers, etc.
6. Pumps, hoisting engines, ventilating machinery, construction and management of hot air, gas and petroleum engines, etc.
7. Machine tools.

Graphical Statics.

Surveying—Railroad surveying: reconnoissance, location of line, calculation of cuttings and embankments.

Ore Dressing—

1. Introduction, theory of separation, hand and machine dressing, general principles governing crushing and sizing of ores of different character.
2. Jigging—theory of, description of different forms of jigs and methods of working, air jigs.
3. Slime treatment, classification of slimes in troughs, spitz kasten, etc., and treatment on buddles and tables.
4. Description of crushing machinery, jaw crushers, rolls, stamps, mills, etc.
5. Sizing apparatus, screens, riddles and trommels.
6. Description of coal-washing plan; anthracite breaker.
7. Description of American ore-dressing works.
8. Foreign ore-dressing works.

Quantitative Analysis—Optional.

Metallurgy—Copper, lead, antimony, silver, gold, zinc, tin, mercury, etc.

Economic Geology—Theory of mineral veins, ores, deposits and distribution of iron, copper, lead, gold, silver, mercury and other metals; graphite, coal, lignite, peat, asphalt, petroleum, salt, clay, limestone, cements, building and ornamental stones, etc.

Drawing—Engineering designing.

Project in Metallurgy, or thesis in mining engineering or economic geology.

II.—Course in Civil Engineering.

First Year.

First Session.

Trigonometry and Mensuration, as contained in Davies' Legendre.

Physics—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Optics—lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—The metals. Lectures and recitations; Fownes' Manual of Chemistry.

Drawing—Free-hand and sketching; lettering, instrumental drawing; projections, intersections and developments. Text-book; Binn's Orthographic Projection.

Second Session.

Geometrical Conic Sections—Text-book: Peck's Conic Sections.

Algebra—Text-book: Peck's Manual of Algebra.

Graphical Algebra—Text-book: Phillips & Beebe's Graphic Algebra.

Graphics—Descriptive geometry; text-book: Church's Descriptive Geometry.

Physics—Magnetism, electricity, static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Drawing—Same as first session.

Summer Vacation.

Memoir.

Second Year.

First Session.

Analytical geometry—Text-book: Peck's Analytical Geometry.

Engineering—Exercises in Mathematical Problems.

Sanitary Engineering—Drainage of buildings and house-lots; water supply of buildings.

Practical Mining—Excavation, quarrying, drilling and blasting. tunnelling.

Zoology—Lectures and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Mineralogy—Lectures, conferences, blow-pipe analysis and crystallography.

Drawing—Topographical drawing; tinting and grading; problems in graphics; scale-construction drawing.

Second Session.

Differential and Integral Calculus—Text-book: Peck's Practical Calculus.

Graphics—Shades and shadows, perspective, isometrical drawing.

Stereotomy—Text-book: Mahan's Stone Cutting.

Engineering—Exercises in mathematical problems.

Sanitary Engineering—Drainage of buildings and house-lots; water supply of buildings.

Practical Mining—Excavation, quarrying, drilling and blasting, tunnelling.

Zoology—Lectures and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—limes, mortars, and cements; building stones: decay and preservation; timber and its preservation; pigments, paints, essential oils, varnishes; glass, and ceremics; explosives: gunpowder, gun-cotton, nitro-glycerine; electro-metallurgy, etc.

Mineralogy—Determinative.

Drawing—Problems in graphics; construction drawing; stone-cutting.

Summer Vacation.

Optional class in machine shops.

Surveying—Lectures, recitations and field work; pacing; compass and chain surveys; topographical work; use of solar compass in land surveys; adjustments and use of transit and wye level for triangulation; traversing, city surveying, and levelling; use of plane table; hydrographic surveys.

Summer class in surveying.

Third Year.

First Session.

Mechanics of Solids, including forces, moments, equilibrium, stability, etc., and elementary machines; dynamics, including uniform, varied, rectilineal, and curvilinear motion, rotation, vibration, impact, work done, etc.

Physics—Mechanical theory of heat, electricity.

Practical astronomy and general principles of geodesy.

Engineering—General principles relating to materials and structures, physically and mechanically considered.

1. Materials—Stone, cements, brick, metals, timber, treated in regard to strength, durability, mode of preparation, defects, tests, of quality, and fitness for special uses.

2. Structures—Earthwork, execution of earthwork, foundations and supports, superstructure, joints, strength and stiffness of parts; special rules of construction for masonry of public buildings, bridges, retaining walls, arches, railroads, common roads, and canals.

Physical properties of materials—Pig-iron: castings, chilled and malleable; wrought iron: bar, shapes, plate, tube and wire; steel: ingot, metal, castings, shapes, and plate; other metals and alloys.

Metallurgy—General metallurgy; fuels, furnaces, etc.

Geology—Lithological, cosmical, and physiographic.

Drawing—General engineering construction; machine construction.

Second Session.

Mechanics of fluids, including pressure, buoyancy, and specific gravities, motion in pipes and channels, undulation, capillarity, tension and elasticity of gases, the atmosphere, the barometer, barometric formulæ, and hypsometry.

Physics—Electricity, physical optics, and the undulatory theory of light (optional).

Practical Astronomy and general principles of geodesy.

Engineering—Theory of strains and strength of materials—elasticity, mechanical laws, application of principles of mechanism to beams, girders, and roof trusses under various conditions of loading and supports.

Physical Properties of Materials—continued from first session.

Metallurgy—Iron and steel

Geology—Historical, including palæontology.

Drawing—General engineering construction; machine construction.

Summer Vacation.

SUMMER CLASS IN PRACTICAL GEODESY.

Memoir.

Fourth Year.

(Without any distinction of sessions.)

Civil Engineering—Hydraulic and sanitary engineering, embracing water supply for cities and towns, for the purposes of irrigation and improvement of lands; quantity and quality of water required; rainfall, flows of streams, storage of water, capacity of watersheds, impurities of water; practical constructiou of water-works, pumping machinery; clarification of water; systems of water supply.

Principles of Sanitary Engineering as regards necessity of sanitary measures, different systems of removing refuse and decomposing matters, warming and ventilation.

Works of Sewerage—Rainfall and sewers; influence of geological and topographical features of the sites of towns and districts; discharge of sewers; intercepting sewers, forms, modes of construction, and materials used; flushing of sewers and ventilation;

traps, outfalls, tide valves; subsoil and surface drainage of towns; house drainage; water-closets; ventilation of houses in connection with sanitary measures.

Improvements of Rivers and Harbors—Action of tides and currents in forming and removing deposits; methods of protecting and deepening harbors and channels.

Engineering—Theory of strains and strength of materials continued—graphical methods of determining strains; deflection of beams and girders; quantity of material in braced girders under various conditions of loading and supports; angle of economy for bracing; torsion of shafts; crushing and tensile strength of materials, working strains and working load; mode of estimating cost of girder work.

Hydraulic Engineering—Application of principles of mechanics of fluids to determining the discharge of water over weirs or dams; the dimensions of conduit pipes; discharge of canals and rivers; the effects of varying forms and sections of channels and of obstructions to flow; the gauging of streams; retaining walls for reservoirs.

Machinery and Millwork—

1. General theory of motion.
2. Uniform and varied motion.
3. Compositon of motions.
4. Instantaneous centre and centroids.
5. Transmissions by rolling and sliding contact, by belting, ropes and chain, by shafting and linkages, by fluids.
6. *Engaging Gears*, reversing and quick-return motions. Dynamics of machinery—forces of nature employed or acting in all machines; dynamical laws, mathematical theorems, measure of forces, work of forces; elementary machines and their combinations; theory of efficiency; theory of fly-wheels, governors and brakes; strength and pro portions of parts of machines; dynamometers; prime movers as driven by animal power, water power, steam power, compressed or heated air, wind power, comprising the theory of animal power, theory of water-wheels, overshot wheels, undershot wheels, breast wheels, turbines, reaction wheels, centrifugal pumps; properties and laws of heat as applied to the generation of steam in steam boilers; properties of steam and air in their relation to prime movers; mechanical theory of heat, applied to steam-engines, hot-air engines, compressed-air engines; general description of heat engines of various forms; description and theory of ventilating fans or blowers.

Mechanical Engineering.—

1. Steam-boilers; construction, wear and tear, fittings, setting, testing, care and management, firing, feeding, injectors, pumps, etc.
2. Mechanism of engines: valve gearing, link motions, governors, etc.
3. Management of engines: erecting, emergencies, special types of engines, etc.
4. Proportions of engines, etc.
5. Testing efficiency of engines and boilers.
6. Pumps, hoisting engines, ventilating machinery.
7. Construction and management of hot-air, gas and petroleum engines, etc.
8. Machine tools.

Graphical Statics.

Railroad Engineering.—Motive power, alignment and grades, economic location, operating expenses; permanent way, track, signal systems: rolling stock; operation and administration.

Geodesy.—Continued with lectures on figure of the earth, astronomical determinations of time, latitude, longitude, and azimuth of a direction.

Surveying.—Railroad surveying: reconnoissance, location and survey of line with curves and slope stakes, calculations of cuttings and embankments; railroad construction.

Drawing.—Engineering designing.

Project.

III.—Course in Metallurgy.

First Year.

First Session.

Trigonometry and Mensuration.—As contained in Davies' Legendre.

Physics.—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Optics.—Lectures, and Atkinson's Ganot's Physics.

Botany.—Lectures, and Bastin's Elements of Botany.

Chemistry.—The metals. Lectures and recitations; Fownes' Manual of Chemistry.

Qualitative Analysis.—Lectures, and Fresenius's Manual of Qualitative Analysis.

Blowpipe Analysis.—Qualitative; text-book: Plattner's Blowpipe Analysis.

Drawing.—Free-hand and sketching; lettering, instrumental drawing; projections, intersections and developements. Text-book: Binn's Orthographic Projection.

Second Session.

Geometrical Conic Sections.—Text-book: Peck's Conic Sections.

Algebra.—Text-book: Peck's Manual of Algebra.

Graphical Algebra.—Text-book: Phillips & Beebe's Graphic Algebra.

Graphics.—Descriptive geometry; text-book: Church's Descriptive Geometry.

Physics.—Magnetism, electricity, static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics.—lectures, and Atkinson's Ganot's Physics.

Botany.—Lectures, and Bastin's Elements of Botany.

Qualitative Analysis.—Lectures, and Fresenius's Manual of Qualitative Analysis.

Crystallography.—Lectures, and Egleston's Diagrams of Crystals.

Drawing.—Same as first session.

Summer Vacation.

Memoir.

Second Year.

First Session.

Analytical Geometry.—Text-book: Peck's Analytical Geometry.

Practical Mining.—Excavation, quarrying, drilling and blasting, tunnelling.

Zoology.—Lectures, and Nicholson's Manual of Zoology.

Hygiene.—Causes of disease, methods of investigation and of prevention, vital statistics, lectures and laboratory practice.

Applied Chemistry.—Lectures and recitations; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Quantitative Analysis.—Lectures, and Cairns' Quantitative Analysis.

Mineralogy.—Lectures and conferences; Egleston's Lectures and Tables of Mineralogy.

Drawing.—Tinting and grading; topographical drawing; construction drawing.

Second Session.

Differential and Integral Calculus.—Text-book: Peck's Practical Calculus.

Graphics.—Shades and shadows, perspective, isometrical drawing.

Stereotomy.—Text-book : Mahan's Stone-Cutting.

Practical Mining.—Excavation, quarrying, drilling and blasting, tunnelling.

Zoology.—Lectures, and Nicholson's Manual of Zoology.

Hygiene.—Causes of disease, methods of investigation and of prevention, vital statistics, lectures and laboratory practice.

Applied Chemistry.—Lectures and recitations; Wagner's Chemische Technologie—limes, mortars, and cements; building stones: decay and preservation; timber and its preservation; pigments, paints, essential oils, varnishes; glass and ceramics; explosives; gunpowder, gun-cotton, nitro-glycerine; electro-metallurgy, etc.

Quantitative Analysis.—Lectures, and Cairns' Quantitative Analysis.

Mineralogy.—Determinative.

Drawing.—Construction drawing; plans of mill buildings, furnaces, etc.

Summer Vacation.

Optional Class in Machine Shops.

Surveying.—Lectures, recitations, and field work; pacing; compass and chain surveys; topographical work; use of solar compass in land and mineral surveys; adjustments and use of transmit and wye level for triangulation; traversing, city surveying, and levelling; use of plane table; stratigraphical and magnetic surveys.

Summer Class in Surveying.

Third Year.

First Session.

Mechanics of Solids.—Including forces, moments, equilibrium, stability, etc., and elementary machines; dynamics, including uniform, varied, rectilineal, and curvilinear motion, rotation, vibration, impact, work done, etc.

Physics.—Mechanical theory of heat, electricity.

Engineering.—General principles relating to materials and structures, physically and mechanically considered.

1. Materials.—Stone, cements, brick, metals, timber, treated in regard to strength, durability, mode of preparation, defects, tests of quality, and fitness for special uses.

2. Structures.—Earthwork, execution of earthwork, foundations and supports, superstructure, joints; stability, strength, and stiffness of parts; special rules of construction for masonry of public buildings, bridges, retaining walls, arches, railroads. common roads, and canals.

Physical Properties of Materials.—Pig-iron: castings, chilled and malleable; wrought-iron: bar, shapes, plate, tube, and wire; steel: ingot metal, castings, shapes and plate; other metals and alloys.

Practical Mining.—

1. Boring, earth augers, driven wells, boring with rods and cable tools; upward inclined, and horizontal boring; diamond drill and its use in prospecting.
2. Shaft sinking, shaft timbering and spiling, boring of shafts, sinking of iron and masonry linings, cribbing, walling, and tubbing.
3. Drifting of adits and levels, timbering and walling in levels and working places.
4. Mining of coal and ores, coal-cutting machines, hand and machine drilling.

5. Handling of coal and ores in working places.

6. Tramming, cars, tracks, locomotive and wire-rope haulage, planes and gravity roads.

7. Accidents to miners, cause and prevention.

8. Organization and administration.

9. Time-books, measurement of contracts, pay-roll, analysis and dissection of accounts and cost sheets.

Quantitative Analysis.

Metallurgy—General metallurgy, fuels, etc.

Geology—Lithological, rocks and rock masses.

Drawing—Constructions ; machines, furnaces, plans, etc.

Second Session.

Mechanics of Fluids—Including pressure, buoyancy, and specific gravities, motion in pipes and channels, undulation, capillarity, tension and elasticity of gases, the atmosphere, the barometer, barometric formulæ, and hypsometry.

Physics—Electricity ; physical optics and the undulatory theory of light (the last two optional.)

Engineering.—Theory of strains and strength of materials continued—graphical methods of determining strains, deflection of beams and girders ; quantity of material in braced girders under various conditions of loading and supports ; angle of economy for bracing ; torsion of shafts ; crushing and tensile strength of materials ; working strains and working load ; mode of estimating cost of girder work.

Dynamics of Machinery—Forces of nature employed or acting in all machines ; dynamical laws, mathematical theorems, measure of forces, work of forces ; elementary machines and their combinations ; theory of efficiency ; theory of fly-wheels, governors, and brakes ; strength and proportions of parts of machines ; dynamometers.

Physical properties of Materials—Continued from first session.

Practical Mining—

1. Boring, earth augers, driven wells, boring with rods and cable tools ; upward, inclined, and horizontal boring ; diamond drill and its use in prospecting.

2. Shaft sinking, shaft timbering and spiling, boring of shafts, sinking of iron and masonry linings, cribbing, walling and tubbing.

3. Drifting of adits and levels, timbering and walling in levels and working places.

4. Mining of coal and ores, coal-cutting machines, hand and machine drilling.

5. Handling of coal and ores in working places.

6. Tramming, cars, tracks, locomotive and wire-rope haulage, planes and gravity roads.

7. Accidents to miners, cause and prevention.

8. Organization and administration.

9. Time-books, measurement of contracts, pay-roll, analysis and dissection of accounts and cost sheets.

Assaying and Ore Testing—Lectures, recitations, and practical work ; sampling and testing large and small lots of ores, slaggs, mattes, alloys, amalgams, etc. ; special practice on lead, antimony, gold, silver, and copper ores.

Metallurgy—Iron and steel.

Geology—Historical, including palæontology.

Drawing—Constructions ; machines, furnaces, plans, etc.

Summer Vacation.

Summer class in practical mining.

Fourth Year.

(Without distinction of sessions.)

Mining Engineering—

1. Considered in its widest sense as a course of study.

2. Considered in reference to the application of general principles of engineering to the development and working of mines.

3. Classification and nomenclature of mineral deposits; descriptions of lodes or veins, beds, masses, and irregular deposits, with illustrations of the disturbances to which they are subjected, as affecting the work of mining.

4. Graphical representations of deposits, with examples showing modes of occurrence and disturbances.

5. Prospecting or searching for mineral deposits.

6. Exploratory workings.

7. Establishing seats of extraction.

8. Description of typical methods of exploitation as applied to wide veins or lodes, to narrow veins, masses, to beds of various thicknesses and degrees of inclination.

9. General principles relating to subterranean transportation.

10. Methods and machinery employed for extracting minerals from the pits, and for facilitating ascent and descent of workmen.

11. Drainage of mines; theory of infiltrations of water, methods and machinery for draining or freeing mines from water.

12. Ventilation of mines; causes of vitiation of the air of mines; quantities of fresh air required under various circumstances; natural ventilation; mechanical ventilation by fires and by ventilating machinery; distribution of air through galleries and workings.

13. Graphical illustrations of exploratory workings; methods of exploitation; machinery for hoisting, pumping, ventilation, and transportation, including the use of steam-engines and pumps, air compressors, air engines, pumping engines, winding engines, centrifugal and other ventilating machines.

Engineering—Theory of strains and strength of materials continued—graphical methods of determining strains; deflection of beams and girders; quantity of material in braced girders under various conditions of loading and supports; angle of economy for bracing; torsion of shafts; crushing and tensile strength of materials; working strains and working load; mode of estimating cost of girder work.

Hydraulic Engineering—Application of principles of mechanics of fluids to determining the discharge of water over weirs or dams; the dimensions of conduit pipes; discharge of canals and rivers; the effect of varying forms and sections of channels and of obstructions to flow; the gauging of streams; retaining walls for reservoirs.

Machinery and Millwork—

1. General theory of motion.

2. Uniform and varied motion.

3. Composition of motions.

4. Instantaneous centre and centroids.

5. Transmissions by rolling and sliding contact, by belting, rope and chain by shafts and linkages, by fluids.

6. Engaging and reversing gears, and quick-return motions.

Dynamics of Machinery—Forces of nature employed or acting in all machines; dynamical laws, mathematical theorems, measure of forces, work of forces; elementary machines and their combinations; theory of efficiency; theory of fly-wheels, governors, and brakes; strength and proportions of parts of machines; dynamometers; prime movers, as driven by animal power, water power, steam power, compressed or heated air, wind power, comprising the theory of animal power, theory of water-wheels, overshot wheels, undershot wheels, breast wheels, turbines, reaction wheels; centrifugal pumps; properties and laws of heat as applied to the generation of steam and the construction of boilers; properties of steam and air in their relation to prime movers; mechanical theory of heat applied to

steam-engines, hot-air engines, compressed-air engines ; general description of heat engines of various forms ; description and theory of ventilating fans or blowers.

Mechanical Engineering.—

1. Steam boilers : construction, wear and tear, fittings, setting, testing, care and management, firing, feeding, injectors, pumps, etc.
2. Mechanism of engines : valve gearing, link motions, governors, etc.
3. Management of engines : erecting, emergencies, special types of engines, etc.
4. Proportions of engines, etc.
5. Testing efficiency of engines and boilers, etc.
6. Pumps, hoisting engines, ventilating machinery ; construction and management of hot-air, gas, and petroleum engines, etc.
7. Machine tools.

Graphical Statics.

Ore Dressing—

1. Introduction, theory of separation, hand and machine dressing, general principles governing crushing and sizing of ores of different character.
2. Jigging—theory of, description of different forms of jigs and methods of working, air jigs.
3. Slime treatment, classifications of slimes in troughs, spitz kasten, etc., and treatment on bundles and tables.
4. Description of crushing machinery, jaw crushers, rolls, stamps, mills, etc.
5. Sizing apparatus, screens, riddles, and trommels.
6. Description of coal-washing plant ; anthracite breaker.
7. Description of American ore-dressing works.
8. Foreign ore-dressing works.

Metallurgy—Copper, lead, silver, gold, zinc, tin, mercury, etc.

Economic Geology—Theory of mineral veins, ores, deposits, and distribution of iron, copper, lead, gold, silver, mercury, and other metals ; graphite, coal, lignite, peat, asphalt, petroleum, salt, clay, limestone, cements, building and ornamental stones, etc.

Drawing—Project and thesis work.

Project.

IV.—Course in Geology and Palæontology.

First Year.

First Session.

Trigonometry and Mensuration, as contained in Davie's Legendre.

Physics—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—The metals. Lectures and recitations ; Fownes' Manual of Chemistry.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Blowpipe Analysis—Qualitative ; text-book ; Plattner's Blowpipe Analysis.

Drawing—Free-hand and sketching ; lettering, instrumental drawing ; projections, intersections, and developments ; Text-book : Binn's Orthographic Projection.

Second Session.

Geometrical Conic Sections—Text-book : Peck's Conic Sections.

Algebra—Text-book ; Peck's Manual of Algebra.

Graphical Algebra—Text-book : Phillips & Beebe's Graphic Algebra.

Graphics—Descriptive geometry ; text-book ; Church's Descriptive Geometry.

Physics—Magnetism, electricity—static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics—Lectures and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Crystallography—Lectures, and Egleston's Diagrams of Crystals.

Drawing—Same as first session.

Summer Vacation.

Memoir.

Second Year.

First Session.

Botany—Histology.

Zoology—Lectures, histology, and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics ; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations ; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Mineralogy—Lectures and conferences ; Egleston's lectures and tables of mineralogy.

Drawing—Topographical drawing ; tinting and grading ; problems in graphics ; sketches of geological outcrops, fossils, etc.

Second Session.

Graphics—Shades and shadows, perspective and isometrical drawing.

Botany—Protophyta, thallophyta, bryophyta.

Zoology—Lectures, and Nicholson's Manual of Zoology ; and practical study of protozoa, recent and fossil.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics ; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations ; Wagner's Chemische Technologie—limes, mortars, and cements ; building stones ; decay and preservation ; timber and its preservation ; pigments, paints, essential oils, varnishes ; glass and ceramics ; explosives ; gunpowder, gun-cotton, nitro-glycerine ; electro-metallurgy, etc.

Mineralogy—Determinative.

Drawing—Geological sections, plain and colored ; fossil drawing.

Summer Vacation.

Surveying—Lectures, recitations, and field work ; pacing ; compass and chain surveys ; topographical work ; use of solar compass in land and mineral surveys ; adjustments and use of transit and wye level for triangulation ; traversing, city surveying, and levelling ; use of plane table ; stratigraphical and magnetic surveys.

Summer class in surveying.

Third Year.

First Session.

Physics—Mechanical theory of heat, electricity.

Botany—Pteridophyta, phanerogamia.

Zoology—Radiata, recent and fossil.

Assaying and Ore Testing—Lectures, recitations, and practical work.

Metallurgy—General metallurgy, fuels, etc.

Geology—Lithological, cosmical, physiographic.

Drawing—Geological drawings.

Second Session.

Physics—Electricity, physical optics, and the undulatory theory of light (last two optional.

Botany—Palæontological.

Zoology—Mullusca, recent and fossil.

Metallurgy—Iron and steel.

Geology—Historical, including palæontology.

Drawing—Geological drawings.

Summer Vacation.

Memoir.

Fourth Year.

(Without distinction of session.)

Botany—Palæontological and economic.

Zoology—Articulata and vertebrata, recent and fossil.

Surveying—Principles of geodesy, railroad surveying, reconnoissance, location of line, calculations of cuttings and embankments.

Quantitative Analysis—Optional.

Metallurgy—Copper, lead, silver, gold, zinc, tin, mercury, etc.

Economic Geology—Theory of mineral veins, ores, deposits and distribution of iron, copper, lead, gold, silver, mercury and other metals; graphite, coal, lignite, peat, asphalt, petroleum, salt, clay, limestone, cements, building and ornamental stones, etc.; economic mineralogy.

Drawing—Dissertation and thesis work.

Thesis.

V.—Course in Analytical and Applied Chemistry.

First Year.

First Session.

Trigonometry and Mensuration as contained in Davies' Legendre.

Physics—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—The metals. Lectures and recitations; Fownes' Manual of Chemistry.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Blowpipe Analysis—Qualitative; text-book: Plattner's Blowpipe Analysis.

Drawing—Free-hand and sketching; lettering, instrumental drawing; projections, intersections and developments; Text-book: Binn's Orthographic Projection.

Second Session.

Geometric Conic Sections—Text-book: Peck's Conic Sections.

Algebra—Text-book: Peck's Manual of Algebra.

Graphical Algebra—Text-book: Phillips & Beebe's Graphic Algebra.

Physics—Magnetism, electricity, static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—Organic; lectures and recitations; Fownes' Manual of Chemistry.

Chemical Physics—Lectures and recitations; Cooke's Chemical Physics.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Crystallography—Lectures, and Egleston's Diagrams of Crystals.

Drawing—Same as first session.

Summer Vacation.

Memoir.

Second Year.

First Session.

Zoology—Lectures, and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics, lectures, and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Chemical Philosophy—Lectures and recitations; Cooke's Chemical Philosophy.

Quantitative Analysis—Lectures, and Cairns' Quantitative Analysis.

Mineralogy—Lectures and conferences; Egleston's lectures and tables of mineralogy.

The Microscope and its Practical Applications—Lectures and laboratory practice.

Second Session.

Zoology—Lectures, and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics, lectures, and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—limes, mortars, and cements; building stones; decay and preservation; timber and its preservation; pigments, paints, essential oils, varnishes; glass and ceramics; explosives; gunpowder, gun-cotton; nitro-glycerine; electro-metallurgy, etc.

Chemical Philosophy—Lectures and recitations; Cooke's Chemical Philosophy.

Quantitative Analysis—Lectures, and Cairns' Quantitative Analysis.

Mineralogy—Determinative.

The Microscope and its Practical Application—Lectures and laboratory practice.

Summer Vacation.

Memoir.

Third Year.

First Session.

Physics—Mechanical theory of heat, electricity.

Applied Chemistry—Lecture and recitations; Wagner's Chemische Technologie.

Chemical manufactures: acids, alkalies, and salts. (1) Sulphur, sulphurous acid, hyposulphites, sulphuric acid, bisulphide of carbon, etc. (2) Common salt, soda ash, hydrochloric acid, chlorine, binoxide of manganese, bleaching powder, chlorates, chlorimetry, etc. (3) Carbonate of potash, caustic potash, alkalimetry, acidimetry, etc. (4) Nitric acid and nitrates. (5) Iodine, bromine, etc. (6) Sodium, aluminum, magnesium. (7) Phosphorus, matches, etc. (8) Ammonia Salts. (9) Cyanides. (10) Alum, copperas, blue vitriol, salts of magnesia, baryta, strontia, etc. (11) Borates, stannates, tungstates, chromates, etc. (12) Salts of mercury and silver. (13) Oils, fats, soaps, glycerine.

Quantitative Analysis.

Metallurgy—General metallurgy, fuels, furnaces, etc.

Geology—Lithological, cosmical, and physiographic.

Biology—Laboratory practice.

Second Session.

Physics—Electricity, physical optics, and the undulatory theory of light (last two optional).

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie.

Food and drink: milk, cereals, starch, bread, meat, tea, coffee, sugar, fermentation, wine, beer, spirits, vinegar, preservation of food, tobacco, etc.

Assaying—Lectures, recitations, and practical work; ores of lead, antimony, tin, bismuth, copper, nickle, iron, mercury, gold and silver; alloys of lead, gold and silver.

Metallurgy—Iron and steel.

Geology—Historical, including palæontology.

Biology—Laboratory practice.

Summer Vacation.

Memoir.

Fourth Year.

(Without distinction of sessions.)

Organic Chemistry—Lectures and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie.

Clothing: textile fabrics, bleaching, dyeing, calico printing, paper, tanning, glue, india-rubber, gutta-percha, etc.

Fertilizers: guano, superphoshates, poudrettes, etc.

Metallurgy—Copper, lead, silver, gold, zinc, tin. mercury, etc.

Economic Geology—Theory of mineral veins ; ores : deposits and distribution of iron, copper, lead, gold, silver, mercury, and other metals ; graphite, coal, lignite, peat, asphalt, petroleum, salt, clay, limestone, cements, building and ornamental stones, etc.

Thesis.

VI.—Course in Architecture.

First Year.

First Session.

Trigonometry and Mensuration—As contained in Davies' Legendre.

Physics—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Optics—lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—The metals. Lectures and recitations; Fownes' Manual of Chemistry.

Drawing—Free-hand and sketching; lettering, instrumental drawing; projections, intersections, and developments.

Second Session.

Geometrical Conic Sections—Text-book : Peck's Conic Sections.

Algebra—Text-book : Peck's Manual of Algebra.

Graphical Algebra—Text-book : Phillips & Beebe's Graphic Algebra.

Graphics—Descriptive geometry ; problems.

Physics—Magnetism, electricity—static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Drawing—Brush work; plans and elevations; ornament; shades and shadows; perspective.

Summer Vacation.

Memoir.

Second Year.

First Session.

Graphics—Descriptive geometry ; problems.

Graphical Geometry—The construction of curves.

The Elements of Architecture—The forms and proportions of the five orders, and of balustrades, steps, doors, windows, arches, vaults, domes, roofs, spires, etc.

Ancient Architectural History—Text-book : Reber's History of Ancient Art, Maspero's Archeologie Egyptienne.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Drawing and Tracing—Free-hand and instrumental; ornament; plans, sections, and elevations.

Second Session.

Graphical Geometry—Continued.

Graphics—Shades and shadows ; perspective, isometrical drawing ; problems.

Stereotomy—Text-book ; Mahan's Stone-Cutting.

The Elements of Architecture—Continued.

Ancient Architectural History—Continued.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics ; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations ; Wagner's Chemische Technologie—limes, mortars, and cements ; building stones ; decay and preservation ; timber and its preservation ; pigments, paints, oils, and varnishes ; glass and ceramics ; explosives : gunpowder, gun-cotton nitro-glycerine ; electro-metallurgy, etc.

Drawing—Ornament from casts ; details ; perspective drawings.

Summer Vacation.

Surveying—Optional.

Memoir.

Third Year.

First Session.

Mechanics of Solids, including forces, moments, equilibrium, stability, etc., and elementary machines.

Engineering—General principles relating to materials and structures, physically and mechanically considered.

1. Materials—Stone, cements, brick, metal, timber, treated in regard to strength, durability, mode of preparation, defects, tests of quality, and fitness for special uses.

2. Structures—Earthwork, execution of earthwork, foundations and supports, superstructure, joints ; stability, strength and stiffness of parts ; special rules of construction for masonry of public buildings, bridges, retaining walls, arches.

Sanitary Engineering—Drainage of buildings and house lots ; plumbing and water supply of buildings.

* *Mediœval Architectural History.*

The History of Ornament—Lectures and exercises.

* *The Theory of Architecture*—The theory of form, conventionalism.

* *Specifications and Working Drawings*—Excavation, foundations, piling, stone-work, brickwork, plastering, and stucco-work : lectures.

Architectural Design—Design by dictation ; problems.

Modelling.

Geology—Descriptive.

Drawing from the Cast—Ornament and the human figure.

* For convenience these subjects are given in alternate years, the third- and fourth-year students taking them together. In 1887-88 both classes take the work here set down for the fourth year ; in 1888-89, that set down for the third year.

Second Session.

Mechanics of Fluids, including pressure, buoyancy, and specific gravities, motion in pipes and channels, undulation, capillarity, tension and elasticity of gases, the atmosphere, the barometer, barometric formulæ, and hypsometry.

Engineering—Theory of strains and strength of materials—elasticity, mechanical laws, application of principles of mechanics to beams, girders and roof trusses under various conditions of loading and supports.

Sanitary Engineering—Drainage of buildings and house lots; plumbing and water supply of buildings.

* *Mediæval Architectural History.*

The History of Ornament—Reports, continued.

* *The Decorative Arts*—Stained glass, pottery, etc.; lectures.

* Business relations; office papers; competitions; legal obligations; superintendence.

Agricultural Design—Alterations and restorations; problems.

Geology—Historical.

Drawing—Historical examples.

Summer Vacation.

Memoir.

Fourth Year.

(Without distinction of sessions.)

Civil Engineering—Theory of strains and strength of materials continued—graphical methods of determining strains; deflection of beams and girders; quantity of material in braced girders under various conditions of loading and supports; angle of economy for bracing; torsion of shafts; crushing and tensile strength of materials; working strains and working load; mode of estimating cost of girder work.

Graphical Statics.

Sanitary Engineering—Ventilation and warming of buildings.

Sewerage.

* *Specifications and Working Drawings*—Carpentry, painting, glazing, plumbing; iron, lead and copperwork; tinning and slating; lectures.

* *Estimates*—Quantity, weight, time, labor, cost; squaring.

* *Modern Architectural History.*

* *The History of Painting and Sculpture.*

* *The Decorative Arts*—Mosaic, fresco, metal works, inlays; lectures.

* *The Theory of Architecture*—The theory of color, the theory of composition.

The History of Ornament—Lectures and exercises.

Economic Geology—Clay, limestones, cements, building and ornamental stones.

Architectural Design—Problems.

Project.

* For convenience these subjects are given in alternate years, the third and fourth-year students taking them together.

VII.—Course in Sanitary Engineering.

First Year.

First Session.

Trigonometry and Mensuration, as contained in Davies' Legendre.

Physics—Doctrines of heat, viz., expansion, conduction, radiation, thermometry, latent heat, tension of vapors, steam, specific heat. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—The metals. Lectures and recitations ; Fownes' Manual of Chemistry.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Drawing—Free-hand and sketching; lettering, instrumental drawing; projections, intersections and developments. Text-book : Binn's Orthographic Projection.

Second Session.

Geometrical Conic Sections—Text-book : Peck's Conic Sections.

Algebra—Text-book : Peck's Manual of Algebra.

Graphical Algebra—Text-book : Phillips & Beebe's Graphic Algebra.

Graphics—Descriptive geometry ; text-book : Church's Descriptive Geometry.

Physics—Magnetism, electricity-static and dynamic, thermo-electricity, induction, magneto-electricity, the electric telegraph. Optics—Lectures, and Atkinson's Ganot's Physics.

Botany—Lectures, and Bastin's Elements of Botany.

Chemistry—Organic ; lectures and recitations ; Fownes' Manual of Chemistry.

Qualitative Analysis—Lectures, and Fresenius's Manual of Qualitative Analysis.

Drawing—Same as first session.

Summer Vacation.

Memoir.

Second Year.

First Session.

Analytical Geometry—Text-book : Peck's Analytical Geometry.

Practical Mining—Excavation, quarrying, drilling and blasting, tunnelling.

The Elements of Architecture.

Zoology—Lectures, and Nicholson's Manual of Zoology.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics ; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations ; Wagner's Chemische Technologie—air, water, artificial illumination, photography.

Quantitative Analysis—Lectures, and Cairns' Quantitative Analysis.

Biology and the use of the Microscope—Lectures and laboratory practice.

Drawing—Topographical drawing ; tinting and grading ; problems in graphics.

Second Session.

Differential and Integral Calculus—Text Book : Peck's Practical Calcus.

Graphics—Shades and Shadows; perspective, isometrical drawing.

Stereotomy—Text-book : Mahan's Stone-Cutting.

Practical Mining—Excavation, quarrying, drilling and blasting, tunnelling.

The elements of architecture continued.

Zoölogy—Lectures, and Nicholson's Manual of Zoölogy.

Hygiene—Causes of disease, methods of investigation and of prevention, vital statistics; lectures and laboratory practice.

Applied Chemistry—Lectures and recitations; Wagner's Chemische Technologie—limes, mortars and cements; building stones; decay and preservation; timber and its preservation; pigments, paints, essential oils, varnishes; glass and ceramics; explosives: gunpowder, gun-cotton, nitro-glycerine; electro-metallurgy, etc.

Quantitative Analysis—Lectures, and Cairn's Quantitative Analysis.

Biology and the Use of the Microscope—Lectures and laboratory practice.

Drawing—Construction drawing : mapping; problems in graphics.

Summer Vacation.

Surveying—Lectures, recitations and field work; pacing; compass and chain surveys; topographical work; use of solar compass in land surveys; adjustments and use of transit and wye level for triangulation; traversing, city surveying and levelling; use of plane table; hydrographic surveys.

Summer class in surveying.

Third Year.

First Session.

Mechanics of Solids—Including forces, moments, equilibrium, stability, etc., and elementary machines; dynamics, including uniform, varied, rectilineal, and curvilinear motion, rotation, vibration, impact, work done, etc.

Physics—Mechanical theory of heat.

Engineering—General principles relating to materials and structures, physically and mechanically considered.

1. Materials—Stone, cements, brick, metals, timber, treated in regard to strength, durability, mode of preparation, defects, test of quality, and fitness for special uses.

2. Structures—Earthwork, execution of earthwork, foundations and supports, superstructure, joints; stability, strength and stiffness of parts; special rules of construction for masonry of public buildings, bridges, retaining walls, arches, railroads, common roads and canals.

Physical Properties of Materials—Pig-iron; castings, chilled and malleable; wrought iron: bar, shapes, plate, tube and wire; steel, ingot metal, castings, shapes and plate; other metals and alloys, especially those used in house-drainage and plumbing.

Sanitary Engineering—Drainage of buildings and house lots; water supply of buildings.

Quantitative Analysis.

Geology—Lithological, cosmical and physiographic.

Drawing—General engineering construction.

Second Session.

Mechanics of Fluids—Including pressure, buoyancy and specific gravities, motion in pipes and channels, undulation, capillarity, tension and elasticity of gases, the atmosphere, the barometer, barometric formulæ, and hypsometry.

Physics—Electricity, physical optics, and the undulatory theory of light (last two optional).

Engineering—Theory of strains and strength of materials—elasticity, mechanical laws, application of principles of mechanism to beams, girders, and roof trusses under various conditions of loading and supports.

Physical properties of materials continued from first session.

Sanitary Engineering—Drainage of buildings and house-lots ; water supply of buildings.

Geology—Historical, including palæontology, or a systematic review of recent and fossil forms of life.

Drawing—General engineering construction; machine construction.

Summer Vacation.

Memoir.

Fourth Year.

(Without distinction of sessions.)

Civil Engineering—Hydraulic and sanitary engineering, embracing water supply for cities and towns, for the purpose of irrigation and improvement of lands; quantity and quality of water required ; rainfall, flows of streams, storage of water, capacity of water-sheds, impurities of water ; practical construction of water-works, pumping machinery; clarification of water; systems of water supply. Disposal of refuse and waste products ; garbage and offal sewage, etc. ; sewage farming, earth filtration, chemical purification.

Hydraulic Engineering—Application of principles of mechanics of fluids to determining the discharge of water over weirs or dams ; the dimensions of conduit pipes ; discharge of canals and rivers ; the effects of varying forms and sections of channels and of obstruction to flow ; the gauging of streams ; retaining walls for reservoirs.

Machinery and Millwork—

1. General theory of motion.
2. Uniform and varied motion.
3. Composition of motions.
4. Instantaneous centre and centroids.
5. Transmissions by rolling and sliding contact, by belting, ropes and chain, by shafting and linkages, by fluids.
6. Engaging gears, reversing and quick-turn motions.

Dynamics of Machinery—Prime movers, as driven by animal power, water power, steam power, compressed or heated air, wind-power, comprising the theory of animal power, theory of water-wheels, overshot wheels, undershot wheels, breast wheels, turbines, reaction wheels, centifrugal pumps ; properties and laws of heat as applied to the generation of steam in steam-boilers, and to heating and ventilation; properties of steam and air in their relation to prime movers ; mechanical theory of heat, applied to steam-engines, hot-air engines, compressed air engines ; general description of heat engines of various forms ; description and theory of ventilating fans or blowers.

Mechanical Engineering—

1. Steam boilers: construction, wear and tear, fittings, setting, testing, care and management, firing, feeding, injectors, pumps, etc.
2. Mechanism of engines: valve gearing, link motions, governors, etc.
3. Management of engines; erecting, emergencies, special types of engines, etc.
4. Proportions of engines, etc.
5. Testing efficiency of engines and boilers.
6. Pumps, hoisting engines, ventilating machinery.
7. Construction and management of hot-air, gas and petroleum engines, etc.
8. Machine tools.

Graphical Statics.

Works of Sewerage—Rainfall and sewers; influence of geological and topographical features of the sites of towns and districts; discharge of sewers; intercepting sewers; forms, modes of construction, and materials used; flushing of sewers and ventilation; traps, outfalls, tide-valves; subsoil and surface drainage of towns; house drainage; the drainage of malarial districts of country, the surface and subsoil drainage of the sites of cities and towns; the construction and management of street pavements; the general principles of heating and ventilation of dwelling-houses, halls of assembly, schools, public buildings, etc., in connection with sanitary and architectural arrangements.

The practical designing of house drainage, and of heating and ventilating apparatus for dwelling-houses, public buildings, hospitals, schools, etc; and methods of computation and investigation for determining the magnitude of heating furnaces, quantity of heating surface, size of blowers or fans for ventilating purposes, size of ventilating air-ducts or conduits and passages, and the general arrangements of the sanitary apparatus in public and private buildings.

Sanitary Jurisprudence—Health organizations; the law of nuisance, specifications and working drawings, etc.

Dangerous trades and occupations.

Drawing—Construction and special; engineering designing.

Project or Thesis.

DEPARTMENTS OF INSTRUCTION.

Mathematics.

The students of the first class attend four hours per week throughout the year. In the first session they are taught trigonometry, plane, analytical, and spherical, with the solution of many practical problems by formulæ and by construction; and the mensuration of surfaces and of volumes. In the second session they complete the subject of algebra, including the general principles and properties of logarithms and the logarithmic series, the general theory of equations, embracing the principal transformations and properties, derived equations and equal roots, Sturm's theorem and the solution of higher equations; and are also taught geometrical conic sections and graphical algebra.

The students of the second class attend four hours per week throughout the year. In the first session, they complete the subject of analytical geometry, with applications to lines and surfaces of the second order; and in the second, the differential and integral calculus, with some of its applications to mechanics and astronomy, as centre of gravity, moment of inertia, falling bodies, attraction of homogeneous spheres, orbital motion, law of force, etc.

Mechanics.

This subject is taught during the third year. The course of instruction embraces the following subjects :

Representation and measurement of forces ; composition, resolution, and equilibrium of forces ; principles of moments and virtual moments ; theory of parallel forces ; application to centre of gravity ; stability.

Elementary machines : friction, resistance to rolling, stiffness of cords, atmospheric resistance.

General equations of motion : rectilinial, uniform, and uniformly varied motion ; curvilinear motion, free and constrained ; centrifugal force ; application to the governor ; vibratory motion ; application to the pendulum ; motions of translation and rotation ; moment of inertia, principal axes, and ellipsoid of inertia ; laws of impact ; centre of percussion ; general theorem of work ; accumulation of work ; application to fly-wheel.

Mechanics of fluids : pressure due to weight ; equal transmission of pressures ; application to hydraulic press ; buoyancy and flotation ; application to specific gravity.

Tension and elasticity of gases and vapors : laws of variation ; application to pumps and siphons ; investigation of the barometer formula ; motion of liquids in pipes and open channels ; living force of fluids ; application to hydraulic ram ; mechanics of capillarity.

Physics.

The students of the first class are occupied during the first term with the subject of heat, including the steam engine, and with the subject of acoustics ; during the second term, in the study of optics, voltaic electricity, magnetism, and electro-magnetism. The courses are fully illustrated by appropriate experiments, and practical problems are occasionally proposed for solution.

To the students of the third class, courses of lectures are delivered on the laws of electrostatics and electrodynamics, electrical constants, dynamo-electrical machines, electric lighting, etc., on the mechanical theory of heat, on mathematical optics, and on the undulatory theory of light. The lectures, except those on the mechanical theory of heat, are fully illustrated by experiments.

The cabinet of physical apparatus will rank with the best on this continent, and extensive additions are made to it each year.

Chemistry.

I.—General Chemistry.

The first class, in all courses, attends two lectures a week in the chemistry of the metals during the first term. The class is divided into four sections, each of which recites once a week to the assistant instructor. It is intended to lay the foundation of a thorough knowledge of the theory of the subject preliminary to the practical instruction in the chemical laboratory. For this purpose the students are drilled upon the lectures, with free use of a text-book. They are expected to write out full notes. At the end of the term they must pass a rigid examination before being admitted to a higher grade. In the course of analytical and applied chemistry, attendance is required twice a week, during the second term, in chemical physics.

During the second term the students of the first class in the courses of analytical and applied chemistry and of sanitary engineering attend two lectures and one recitation per week in organic chemistry.

During the second term of the first year the students in the course of analytical and applied chemistry attend two recitations per week in chemical physics.

The second class, in the course of analytical and applied chemistry, attends four recitations per week throughout the year, in Cooke's Chemical Philosophy.

II.—Analytical Chemistry.

There is a laboratory devoted to qualitative analysis, another to quantitative analysis, and an assay laboratory. These laboratories are provided with all the necessary apparatus and fixtures, and each is under the special charge of a competent instructor, with an assistant. Each student is provided with a convenient table, with drawers and cupboards, and is supplied with a complete outfit of apparatus and chemical reagents.

During the first year, qualitative analysis is taught by lectures, blackboard exercises, and recitations, and the student is required to repeat all the experiments at his table in the laboratory. The class is divided into four sections, each of which recites once a week to the assistant instructor. Having acquired a thorough experimental knowledge of the reactions of a group of bases or acids, single members of the group or mixtures are submitted to him for identification. He thus proceeds from simple to complex cases, till he is able to determine the composition of the most difficult mixtures.

When the student shows, on written and experimental examinations, that he is sufficiently familiar with qualitative analysis, he is allowed to enter the quantitative laboratory.

During the second and third years, quantitative analysis is taught by lectures and recitations, and the student is required to execute in the laboratory in a satisfactory manner, a certain number of analyses. He first analyses substances of known composition, such as crystallized salts, that the accuracy of his work may be tested by a comparison of his results with the true percentages.

These analyses are repeated till he has acquired sufficient skill to insure accurate results. He is then required to make analyses of more complex substances, such as coal, limestones, ores of copper, iron, zinc, and nickel, pig-iron, slags, air, water, foods, disinfectants, technical products, etc.,—cases in which the accuracy of the work is determined by duplicating the analyses and by comparing the results of different analyses.

Volumetric methods are employed whenever they are more accurate or more expeditious than the gravimetric methods, In this way each student acquires practical experience in the chemical analyses of the ores and products which he is most likely to meet in practice.

The Summer School in Chemistry.—The qualitative and quantitative laboratories will be opened from June 15th to September 15th, for students in qualitative, quantitative, and sanitary analysis. The instruction will be by lectures, recitations, and laboratory practice. Examinations will be held for all those who wish certificates of proficiency.

III.—Organic Chemistry.

The general principles of this subject are taught by lectures and recitations during the second session of the second year. More detailed instruction is given to the students in the course of analytical and applied chemistry during the fourth year, when they are admitted to the organic laboratory. This instruction continues during the entire year, and consists of lectures, recitations, informal blackboard conferences in the laboratory, and analytical and synthetical work at the laboratory table.

The laboratory work of each student consists of:

(1) Ultimate analyses, including determinations of carbon, hydrogen, nitrogen, sulphur, and haloid elements in organic substances; determination of vapor densities, specific gravities, melting and boiling points, and calculation of formulæ.

(2) Preparation by synthesis, of a limited number of organic compounds. The student is taught to apply, experimentally, the reactions learned in the lecture-room, the object being to familiarize him with the various methods of synthesis.

(3) Applications of organic chemistry to the arts; especially the use of the artificial coloring matters, prepared by the students, such as rosanilin, alizarin, indigo, etc., to dyeing and calico printing, and the testing of commercial colors and mordants.

(4) A complete but concise memoir on each substance prepared, including its history, preparation, constitution, properties, applications, and a list of references to its literature.

IV.—Assaying.

During the third year, the student is admitted to the assay laboratory, where he is provided with a suitable table and a set of assay apparatus, and where he has access to the sampling and ore-testing machinery, crucible and muffle furnaces, and to volumetric apparatus for the assay of alloys.

The course includes :

1. Lectures and recitations. 2. Practical work.

The lectures treat of and describe the furnaces, fuels, apparatus, reagents, etc., employed, and explain the general principles as well as the special methods of sampling and assaying. Models and lantern views of the furnaces and apparatus are shown, and the ores of the various metals and the appropriate fluxes are exhibited and described. The recitations follow the lectures, and are held by the assistant instructor, the class being divided into small sections for the purpose.

The practical work includes the testing of reagents and small samples of ore, practice on methods, and special work to familiarize the student with sampling large lots of ore, and to give practice in mill and furnace assay.

The student is supplied with the different ores, and is required to assay each, under the immediate supervision of the instructor.

To facilitate the assay of ores of the precious metals, a system of weights has been introduced, by which the weight of the silver or gold globule obtained shows at once, without calculation, the number of troy ounces in a ton of ore.

To furnish necessary facilities for practical work, the following plant has been provided :

1st.—Arrangements for sampling large and small lots of ore. These consist of crushers, rolls, sizing sieves, Hendrie and Bolthoff pulverizer, sampling and grinding plates.

2nd.—Appliances for milling and amalgamation, such as small stamp mill, plates, steam-jacketed pan, settler, retorting apparatus for amalgam, etc.

3rd.—Concentration appliances, both by hand and machine work, such as pans, jigs, Frue Vanner, Golden Gate concentrator, etc.

4th.—Furnaces for roasting and smelting, with small plant for making leaching tests of chloridized ore.

The machinery is run by one fifteen-horse power engine. In order to make the plant as practical as possible, the arrangement, as far as space will permit, is the same as is usual in milling and concentrating ores on a large scale. In following out the course of instruction, lots of 500 lbs. of ore in lump are given out to the students, who are required to sample and assay the same, and then, from the assay and mineral characteristics of the ore, determine upon a method of treatment. If the ore is one which should be concentrated, the students to whom the sample is assigned will size it, concentrate by different methods, assay the concentrates, middlings, tailings, etc., and make up a clear statement as to the method and the results, giving an opinion, founded upon the facts observed, as to how the ore should be treated.

V.—Applied Chemistry.

The instruction in applied chemistry extends through the second, third, and fourth years, and consists of lectures and recitations illustrated by experiments, diagrams, and specimens. Wagner's Chemische Technologie is used as a text-book.

The subjects discussed are :

In the Second Year.

(For all students.)

I. Air: nature, sources of contamination, sewer gas, plumbing, draining, disinfection, ventilation.

II. Water : composition of natural waters, pollution, disposal of sewage and house refuse.

III. Artificial illumination : candles, oils, and lamps, petroleum, gas and its products, electric light.

IV. Photography.

V. Limes, mortars, and cements.

VI. Building stones : decay and preservation.

VII. Timber and its preservation : pigments, paints, essential oils, varnishes, preserving process.

VIII. Glass and ceramics.

IX. Explosives : gunpowder, gun-cotton, nitro-glycerine, etc.

X. Electro-metallurgy.

In the Third and Fourth Years.

(For students in the course of analytical and applied chemistry.)

I. Chemical manufactures : acids, alkalies, and salts.

(1) Sulphur, sulphurous acid, hyposulphites, sulphuric acid, bisulphide of carbon, etc.
(2) Common salt, soda ash, hydrochloric acid, chlorine, binoxide of manganese, bleaching powder, chlorates, chlorimetry, etc.
(3) Carbonate of potash, caustic potash.
(4) Nitric acid and nitrates.
(5) Iodine, bromine, etc.
(6) Sodium, aluminium, magnesium.
(7) Phosphorus, matches, etc.
(8) Ammonia salts.
(9) Cyanides.
(10) Alum, copperas, blue vitriol, salts of magnesia, baryta, strontia, etc.
(11) Borates, stannates, tungstates, chromates, etc.
(12) Salts of mercury and silver.
(13) Oils, fats, soaps, glycerine.

II. Food and drink : milk, cereals, starch, bread, meat, tea, coffee sugar, fermentation, wine, beer, spirits, vinegar, preservation of food, etc.

III. Clothing : textile fabrics, bleaching, dyeing, calico, printing, paper, tanning, glue, india-rubber, gutta-percha, etc.

IV. Fertilizers : guano, superphosphates, poudrettes, etc.

Geology and Palæontology.

The course of instruction in this department is as follows :

Second Year.

Botany and zoology, as an introduction to palæontology—lectures throughout the year.

Third Year.

Lithology : minerals which form rocks and rock masses of the different classes—lectures and practical exercises.

Geology : cosmical, physiographic, and historical—lectures and conferences throughout the year.

Fourth Year.

Economic geology : theory of mineral veins ; ores ; deposits and distribution of iron, copper, lead, gold, silver, mercury, and other metals ; graphite, coal, lignite, peat, asphalt, petroleum, salt, clay, limestone, cements, building and ornamental stones, etc.,—lectures and conferences throughout the year.

Mineralogy and Metallurgy.

I.—*Mineralogy.*

The studies in mineralogy continue throughout two years. During the first year the students are instructed in the use of the blowpipe, in crystallography, and in theoretical mineralogy.

The instruction in blowpipe analysis is entirely practical, and lasts through the first half of the year. It consists in instruction how to use the different flames, and in teaching the students how to examine mixtures, alloys, and natural compounds, so that they are able to determine with ease the constituents of a mixture containing a large number of simple substances. In order to do this, substances whose composition they know are given to them, upon which they are required to perform all the characteristic reactions which take place in the different flames with the different fluxes. After they are sufficiently familiar with the behavior of substances, the composition of which they know, they are given substances, the composition of which they do not know, to determine.

The collection of blowpipe substances consists of four hundred alloys, mixtures, and minerals. Students are taught to examine, qualitatively, all the different commercial alloys, and a large number of the natural combinations which exist in minerals. The blowpipe laboratory is a large, well-ventilated room to which the students have access at all hours of the day, where each student has a drawer with a lock, assigned to him, which he retains until the close of the term.

At the commencement of the second term the lectures on crystallography commence. They embrace the entire subject of crystallography, including the descriptions of both normal and distorted forms, for the study of which the students have access to a collection of over 300 models in wood, embracing all the theoretical forms. Besides this collection, they have the use of the collection of 150 models in glass, and have access to the collection of minerals, most of the species of which are illustrated by models in wood, showing the perfect and distorted crystallographic forms.

Conferences are held during the term, in which the students are required to determine models of the theoretical forms as well as those found in minerals. They are also taught theoretical mineralogy, including the optical and physical properties of minerals, the lectures being illustrated by a very complete set of apparatus, presented by F. A. Schermerhorn, and a cabinet containing a large number of sections of minerals for lantern and instrumental use. For the study of sections the students are taught the use of Groth's polariscope and of goniometers.

At the commencement of the second year the students begin the study of practical mineralogy. They are required to determine minerals by the eye, or by asking questions with regard to those characteristics which cannot be determined without experiment. They are required to give the name, the composition, the crystalline form, and the prominent chemical and physical characteristics of the mineral they determine. To facilitate this work they have unrestricted access to a collection of over 3,000 carefully labelled specimens on which they are allowed to make any experiments. They have besides constant access to the cabinet of minerals, which contains about 30,000 specimens, arranged in table cases to show the different characteristics of minerals, and about 3,000 specimens arranged in wall cases to show their associations. The crystals of minerals are arranged upon pedestals in such a way that they can be readily seen and examined by the students.

At the commencement of the second term of the second year they are required to determine such minerals as they are likely to find in the field, by testing them with a blowpipe and such reagents and instruments as they are likely to have in the outfit of an ordinary survey.

The instruction in mineralogy for civil engineers is given in the second year of the course. It comprises a brief course in blowpipe analysis, sufficient for the determination of simple mixtures and minerals, a series of lectures upon the rock-forming minerals, their occurrence, their effect upon building stones, and the methods for their determination, and the study of these minerals in a special collection.

Most of the instruments in this department were presented to the school by D. Willis James, C. R. Agnew, and the late Gouverneur Kemble. The collection of minerals was founded by a valuable collection presented as the first donation to the school, before it was opened in 1864, by the late George T. Strong of this city. It was shortly afterward supplemented by another collection presented by the late Gouverneur Kemble, containing many autographs and specimens from the cabinet of of Hauy. As these collections were both very rich in duplicates, very many valuable additions have been made to the cabinet by exchange. Collections were also made in Europe during several years by the professor in charge, having the necessities of the collection of the school in view, and were presented to the school through the generosity of Morris K. Jesup, Wm. E. Dodge, jr., D. S. Egleston, C. Lanier, and J. Crearer of this city, and the late John H. Caswell, Wm. H. Aspinwall, and R. P. Parrott.

II.—Metallurgy.

The lectures in metallurgy continue through two years, and discuss in detail the methods in use in the best establishments in this country and in Europe for working ores. They embrace:

(*a*) General metallurgy.
(*b*) The metallurgy of iron.
(*c*) The metallurgy of steel.
(*d*) The metallurgy of the metals.

(*a*) *General Metallurgy.*—The lectures in general metallurgy embrace the subjects of combustion, fire-clays, furnaces, natural fuels (wood, peat, lignite, bituminous and anthracite coals), artificial fuels (charcoal, peat charcoal, and combustible gases manufactured in producers), chimneys, the different kinds of blast engines, regulators, hot-blast ovens, and tuyeres.

(*b*) *The Metallurgy of Iron.*—The metallurgy of iron consists in the discussion of the general properties of iron ores and slags, lifts, the theory of the blast-furnace process (the causes of variation in the working produced by the blast, by the fuels, by the variations in the charge, and by the form of the furnace), the effects of moisture, the methods of ascertaining the cost, the calculations of the heat developed and lost in the furnace, molding, melting the iron in crucibles, cupolas, and reverberatory furnaces, the methods of making the moulds, the precautions required in casting, and the manufacture of malleable cast-iron.

In the manufacture of wrought-iron from cast-iron, there are discussed: the German process and its modifications, the English processes, including fining, the dry and boiling processes in puddling, stationary and rotary furnaces, shears, hammers, squeezers, saws, rolls, reheating in ordinary and regenerator furnaces, two- and three-high trains, and the method of calculating cost of wrought-iron.

In the direct processes of the manufacture of iron from the ore the Catalan process and its derivatives are discussed.

(*c*) *The Metallurgy of Steel.*—In the metallurgy of steel there are discussed the processes of manufacture of: low-furnace and puddled steel, cement steel, crucible steel, basic and acid Siemens-Martin steel, basic and acid Bessemer steel, the utilization of scrap iron, and the manufacture of sheet-iron, nails, wire, and rails.

(*d*) *The Metallurgy of the Metals:*

Copper.—The lectures on copper include: the treatment of native copper; the treatment of pure sulphurous ores by the Swedish, German and mixed methods, in Europe and the United States; thetreatment of rich pure ores; the treatment of impure ores in the Hartz mountains and in the United Stases; the treatment of very poor ores by lixiviation; the treatment of rich and pure ores by the English methods in the reverberatory furnace in the United States and Europe, and the treatment of rich and impure ores in the same furnace; the treatment of oxidized ores in the United States and Europe; the mixed methods in Europe and in the United States; the treatment of oxides, and the wet methods.

Lead.—The lectures on lead include: the method of roasting and reaction in France, England and the United States; the method of roasting and reduction; method by precipitation in France, Germany, and the West; the mixed method in France, Germany, and the West; the refining of lead; the extraction of silver by the Pattinson method and by zinc; cupellation. and condensation of volatile products.

Silver.—The lectures on silver include: the treatment of silver ores in furnaces in Germany and in the United States; the separation of silver by Saxon, Mexican, or pan amalgamation; the treatment in the wet way, by Augustin's method, Ziervogel's method, Von Patera's method, and Russel's method, and the refining of silver.

Gold.—The lectures on gold include: washing, sluicing, hydraulic mining, Plattner's process, parting gold and silver.

Tin.—The lectures on tin include: the treatment of tin in shaft furnaces and in reverberatory furnaces.

Zinc.—The lectures on zinc include: the Silesian, Belgian, and English methods.

Mercury.—The lectures on mercury include: the treatment of ores of mercury by precipitation and by roasting.

There are also discussed the treatments of ores of antimony, nickel and cobalt, and bismuth.

It is designed to make these lectures as practical as possible, and for this purpose the economic details of cost are given whenever they can be obtained from authentic sources. Special attention is given to the ores of this country which are difficult to treat, to the solution of practical problems which may occur, and to changes which different economic relations are liable to cause in the treatment of the same ore in different localities.

During the year the students of both classes are questioned once a week by an assistant, and the points not thoroughly understood are further explained.

Nearly a thousand lecture diagrams and the same number of photographic illustrations, for use in the lantern, have been prepared to illustrate the furnaces, machines, and appliances used in the different metallurgical works, as well as to illustrate the construction of furnaces, etc.

The collections illustrating the department of metallurgy include models of furnaces and a very large number of drawings and tracings, in most cases copies from the working drawings of establishments in actual operation. This collection embraces several hundred tracings collected from the best types of works in this country and abroad, many of them being sufficiently detailed to be used as construction drawings.

The metallurgical collection, properly speaking, embraces about 3,000 specimens, illustrating every stage of all the prominent metallurgical processes. Many of these specimens have been analyzed or assayed. They are constantly open to the inspection of the students.

As an application of the lectures, the students are required to work out a project and to present working drawings and estimates for the erection of works to treat a given ore under stated conditions. The problems given are those which require solution in some parts of the United States.

Engineering.

Engineering, in its widest sense, involves applications of the sciences of physics, mechanics and chemistry to a great variety of problems met with in works and enterprises of a public and private nature or of an industrial character, in which the employment of materials, the building of structures, the use of machinery, the utilization of natural resources, or the protection or improvement of the ways of commerce are essential and important elements and conditions. The educated engineer, whatever may be the branch of the profession to which he devotes himself, should, therefore, have a thorough foundation of knowledge in certain subjects of common application—for example, free-hand and instrumental drawing, mathematics, physics, and mechanics, and the application of these sciences to the resistance of materials, to machinery, to structures of iron and wood and masonry; the flow of streams in artificial channels required for water-works, drainage,

and for sanitary purposes ; the theory of heat as applicable to air and steam in their various uses, in ventilation, etc.

The courses in mining engineering and civil engineering are, therefore, identical in all that pertains to these subjects.

It is essential, however, that in each of these branches of engineering, the subjects technically appertaining to each should receive as great a share of the attention of the students in the courses in mining and civil engineering respectively, as possible in the short period devoted to collegiate instruction.

The mining engineer encounters in his practice questions which are rarely met with in civil engineering—for example, the results of experience in the searching for, winning, and exploitation of mineral deposits, special problems in ventilation and drainage ; while, on the other hand, he is seldom or never called upon to discuss questions which are common and important in the practice of civil engineering, such as the supply of water to towns and cities, and other sanitary works on a large scale, the erection of extensive public buildings, the improvement of harbors and rivers, works of irrigation, the building of extended bridges, etc.

The arrangement of the two courses in engineering has been made under the above views of the subject, utilizing, as it does, in the best manner, the time of the instructors, and avoiding a repetition of the same instruction to different classes.

The collateral branches of study for the engineering courses, chemistry, metallurgy, geology, subjects quite as essential to mining and civil engineers as physics and mechanics, have also been assigned to these two courses, in accordance with the general requirements of the respective professions.

I.—Drawing, Descriptive Geometry, etc.

The course in drawing embraces instrumental drawing, descriptive geometry, shades, shadows, and perspective, stone-cutting, isometric drawing, topographical and geological drawing, drawings of engineering constructions and machinery.

The first year is devoted to the elements of instrumental drawing, the use of instruments, lettering, projections of objects, plans, sections and elevations, intersection of solids and of surfaces, and the development of surfaces.

During the vacation which follows, the execution of sketches from nature and from engineering and architectural constructions is required.

During the second year, the first session is occupied in the study of descriptive geometry, in grading and tinting, as well as in topographical drawing.

The instruction in these subjects requires all problems and illustrations to be carefully and neatly executed on the drawing-board, and the principles of construction explained by the student in oral examinations.

During the second session, the subjects of shades and shadows, perspective and isometrical drawing, and stone-cutting, are taken up in the same manner. Practice is also given in drawing the simple elements of architecture, such as the plans of private and public buildings, showing the details of walls, floors, windows, and door casings, etc.

The drawing of the third year includes work from models and from blue prints, etc., furnished by various machine shops and engineering firms. General engineering construction drawing is taught first ; then a systematic method of machine construction drawing, accompanied by lectures. Maps are also drawn from field-work executed by the students themselves.

During the vacation which follows, the necessary drawings for memoirs are made.

The drawing and engineering designing of the fourth year are intimately connected. A variety of strain sheets of graphic statics are first drawn, and the remainder of the time is devoted to the designing of engineering structures, including the making of bills of materials and complete working drawings.

The whole course of drawing is progressive, and embraces nearly 100 sheets, each succeeding sheet being illustrative of a principle of construction or an advance toward more difficult methods or combinations ; and it is designed to qualify students for the execution of all kinds of drawing and the most difficult constructions.

II.—*Surveying.*

The instruction in surveying is given in a special summer class during the vacation between the second and third years. Six weeks are devoted to practical work in the field, supplemented by lectures and instruction in the theory of surveying, and office work for the computation of surveys and construction of maps.

The students are divided into squads of two men, each squad being provided with instruments, and required to execute a certain number of surveys. Each survey is preceded by class exercises, intended to familiarize the students with the details of the work, and each survey forms the subject of a report, with computations, maps, etc.

At first these surveys and exercises are without instruments, the students being drilled in methods of ascertaining distances and making rough surveys by pacing, and by employing the height of the body, the length of the arm, etc., for making measurements when instruments are not available.

These exercises are followed by others with chain, sight-poles, hand-level, and other equally simple forms of apparatus, and by a topographical survey, showing the application of such rough and rapid methods of work for reconnoissance surveys demanding approximate accuracy only. Next the students make surveys with the ordinary surveyor's compass and chain, and with the solar compass, and magnetic surveys with the attraction compass and dipping needle.

Finally, they are practised in the adjustments and use of the more accurate instruments, including field-work in triangulation, traversing, and levelling, and surveys with the plane table.

The following exercises and surveys are required of each squad of students:—

1. Exercises for determining length of pace, and practice in pacing.

2. Survey of a field by pacing.

3. Exercises in sketching contour lines and topographical details—two examples.

4. Exercises in chaining over level and sloping ground, and in construction of right angles and parallel lines with chain.

5. Exercises in ranging straight lines with sight-poles under different conditions.

6. Exercise in reading compass bearings.

7. Survey, with compass and chain, of a farm of about twenty acres, including location of fences, roads, and farm buildings, correction of bearings for local attraction, computation of latitudes, departures and area, and a plat.

8. Adjustment of hand-level and exercise in levelling.

9. Topographical survey on rectangular plan, with compass, chain, and hand-level, determining minor details by pacing, with finished map of area surveyed.

10. Adjustments of the transit.

11. Triangulation. As an exercise for practice in the use of the transit each squad is required to make three or four sets of readings of each angle of a triangle, each set including six repetitions.

12. Determination of true meridian, by observation on Polaris.

13. Traverse of a polygon of about twelve sides, the angles being repeated and the sides measured with a steel tape, with allowances for catenary, temperature, and inclination. Computation of ordinates and abscissas, and a plat.

14. Adjustment of telemeter wires and measurement of distances by telemeter.

15. Azimuth traverse of a polygon, distances by telemeter readings.

16. City survey. Exercise in laying out city lots and in determining exact position of house and fence lines—report and plat.

17. Adjustments of the wye level.

18. Line of levels, about one mile in length, determining levels of stations 100 feet apart, and of benches.

19. Plane-table survey. Each squad of two men is required to make a survey of about 70 acres, determining all topographical details, and locating contours 20 feet apart.

20. U. S. mineral survey, with the solar compass, of a mining claim 150 feet by 1500, complying with the requirements of the Land Office and the instructions of the Surveyor-General.

21. Hydrographic survey. For this survey the squads are increased to six men, and each squad is required to survey about 30 acres, making about 250 soundings, each sounding being located by two transits.

The mining-claim survey is required of students in the courses of mining engineering and metallurgy, and the hydrographic survey of students in the course of civil engineering.

22. A magnetic survey with attraction compass and dipping needle, and a stratigraphic survey, with construction of geological sections and lines of outcrops, may replace, for students in mining engineering, one or more of the exercises above noted.

In the vacation between the third and fourth years, the students of mining engineering, during the session of the summer school of practical mining, make underground surveys and construct maps and sections of the mines visited.

During the fourth year a line of railroad is surveyed, locating the line on the ground, setting grade and slope stakes, levelling, and calculation of cuttings and embankments, drawings and estimates. In addition, the course in railroad engineering for the civil engineers embraces practical lectures on railroad construction, permanent way, rolling stock, motive power, and administration of railroads, with instruction in the economics of location and transportation.

III. Civil Engineering.

Instruction in civil engineering extends through the third and fourth years.

During the third year, the more simple elements of civil engineering and surveying are taught. In civil engineering the various subjects are considered in the following order: first, materials—building stones, limes, cements, mortar, concrete, brick, wood, metals; their properties and general qualities, mode of preparation, and their respective uses, and combinations in construction, their strength and durability: second, masonry—construction of masonry, retaining walls, arches, etc.: third, framing—structures of wood, carpentry: fourth, stone and wooden bridges—descriptions of various kinds of wood and iron trusses in use, suspension bridges, etc., general principles of roof construction: fifth, common-road construction—general principles of railway construction; construction of canals, general principles of rivers, slack-water navigation, etc.

The course of civil engineering in the fourth year embraces the principles of mechanics applied to engineering constructions and to machinery, the strength of materials, the theory of retaining walls and arches, and the methods of determining the dimensions of the parts of iron roof and bridge trusses, by means of the stresses to which they are subjected, the theory of such structures and the details of practical construction; the principles of hydraulics applied to the improvements of rivers, the water supply of towns, reservoirs, dams, etc.; and the general principles of sanitary engineering, drainage, sewers, house drainage, and ventilation.

A course of lectures, fifty or sixty in number, is delivered during the third year to students in civil and mining engineering on the properties of the metals used in engineering constructions. These lectures are devoted principally to iron and steel, but include also other metals and alloys. They treat of the mechanical processes by which these metals are transformed into the shapes required by the engineer, from the crude state in which they are found, after reduction by metallurgical processes from their ores. The physical properties of such fabricated materials, under the various uses and conditions to which they are subjected in engineering construction, are also treated. The lectures are intended to cover, as far as possible, a field of knowledge which of late years has grown into great importance and prominence as an essential branch of an engineer's acquirements, and which connects the science of metallurgy with the art and practice of

engineering. This field embraces not only the arts of fabrication of merchant forms, but also the physical and mechanical properties of the metals in such forms: such as coefficients of strength, limits of elasticity, ductility, adaptability for particular uses and different conditions, etc., which vary greatly with the processes through which the metals have passed, and yet from their nature required to be treated in connection with engineering problems. Instruction is also given in inspection and testing of these materials delivered under contract, embracing the usual practical, physical tests, and the relations so far as known between chemical analysis and physical characteristics.

In view of the paramount importance of iron and steel to the engineer of to-day, considerable time is devoted to these metals. The inspection and grading of pig-iron, and the suitability of different grades for various kinds of castings; cupola furnaces and cupola mixtures and their effects upon product; special dangers inherent in castings of certain shapes; principle in design of castings; shrinkage strains and lines of weakness in castings; defects due to cores and to moulds; resistance of cast-iron to corrosion and protection from it; inspection of castings—these are included in a first series.

Chilled castings—their characteristics, uses, production, and dangers—and malleable castings are similarly treated, including their action under heat and under tools, and the brazing of castings.

Under the head of wrought iron are discussed: piling, heating and rolling of muck bar; effects of heating and rolling on merchant bar; forge uses and tests of bar; requirements of metal for plate, for tube, for wire, and for special forged shapes, such as bolts, etc.; heating, piling, and rolling for shapes or structural iron; points of defect, characteristics of different shapes, adaptability for different uses; possible sections and areas; combination of sections; protection from corrosion; inspection of structural iron; fabrication of ship and boiler plate; methods and processes, properties, defects, requirements, and inspection; fabrication of tube and pipe, lap and butt welded; continuous and universal mills, bending, welding, and straightening rolls, swaging, testing, and tool work; fittings, forms, and uses.

Under the head of steel are treated: properties of crucible steel resulting from its manufacture, such as uniformity of temper, adaptability for tools and cutters; Bessemer and Siemens-Martin steels; properties of ingot metals, mill and furnace treatment for shapes, springs, tires, bars, and plate; characteristics of ingot plate, effects of alloying impurities; steel castings; their production, characteristics and defects; iron and steel forging: drop forging, die forging, machine forgings, large and small, heating and handling, excellences and sources of defects; burnt iron and steel.

Incidentally to these topics is discussed the machinery for handling the materials in process of manufacture, so far as they are essential to the primary object in view.

After iron and steel follow lectures upon a similar plan, discussing brass—cast, rolled, and drawn, copper sheet sand tubes, lead pipe and sheets, zinc and tin—sheet and tube, and galvanized and tin plate, certain alloys for special needs against friction, corrosion, etc., and the brazing and soldering processes for the various metals receive attention at the close.

The students in the civil-engineering course are also instructed in the principles of mechanism, beginning with the general theory of motion; the principles of transmission of motion, the various modes of mechanical connection, the calculation of relative velocities of moving pieces of machinery, valve-gearing, and the mechanism, movements, and construction of machinery in practice; the dynamics of machinery or the determination of the relations between the forces which act upon machines and the general application of mechanics to machines; the study of prime movers, including steam-engines, hot-air engines, and water-wheels; the theory and construction of steam-boilers, and the general principles of heat, as applied to air and vapors.

IV. Mining Engineering.

The course of mining engineering is the same as that in civil engineering, in drawing and surveying, except that the students of mining have additional instruction in underground surveying and geological reconnoissance. The courses in mining and civil

engineering are also identical during the third year in all that relates to materials and general principles of engineering constructions, excepting that the course in mining engineering is intended to be more extended in the principles of mechanism and construction of machinery, and less extended in the detailed principles of roof and bridge construction, hydraulics as applied to river improvements, sanitary engineering, water supply of towns, etc.

During the second and third years, the course in mining engineering embraces lectures on practical mining, or miner's work, including excavation of clays, peat, bog-iron ore, and other easily worked materials; quarrying for extraction of large blocks of stone, marble, etc.; blasting, drilling tools, hand-boring, use of explosives; well-boring, by hand for exploration, and machine-boring; sinking of shafts and slopes, timbering and driving of adits and levels; in the use of picks and gads in the mining of coal, salt, fire-clay, and other soft rocks, coal-cutting machines, mining of ores and hard rocks, handling of excavated mineral in working places, underground transportation, tramming by man or animal power; mechanical haulage with chains or wire rope, and by underground locomotives; accidents to men, their cause and prevention; organization and administration; mine book-keeping accounts with men, time-books, pay-roll, analysis and dissection of mine accounts and making out of cost sheets.

Attendance upon the summer class of practical mining is obligatory for students of mining engineering. The class visits mines and engages in underground work and the study of mine plant and method, under the immediate direction of competent instructors.

The instruction in mining engineering during the fourth year is the same as for the civil engineers in all that relates to the general dynamics of machinery, and to the application of the principles of mechanics to engineering construction and to the physical properties of materials. It is more extended in the application of machinery to mining purposes, especially in connection with the use of compressed air, pumping and ventilating machinery, and hoisting machinery.

It embraces also the study of mineral deposits; classification and description of veins, beds, and masses, and their geological characteristics, interruptions and intersections, methods of prospecting, of reaching deposits, of prosecuting the underground workings, and methods of making and supporting excavations made for special purposes, junctions of levels, chambers for machines, and of making and supporting excavations in watery strata; proper provision for pumping and ventilation; general principles to be observed in laying out, opening and working mines, and methods applicable to special deposits, such as narrow and wide veins or lodes, thick and thin seams of coal; hydraulic mining, etc.; also instruction in the proper administration of mining works, exterior transportation, mine regulations, etc.

A course of lectures on ore dressing inclndes the general principles of ore dressing, preliminary hand dressing, and sorting and preliminary cleansing and sizing; crushing by hand and with machinery; cleansing in ditches and troughs, in sieves, trommels, and by special machines; sizing, bar gratings, and other stationery screens, riddles, revolving screens, concentration of coarse and fine material by jigs, buddles, tables, etc., ; illustrations from American and foreign practice; mechanical preparation of coal and other minerals, and the concentration and purification of copper, lead, iron and other ores.

Sanitary Engineering.

The course in sanitary engineering includes that of civil engineering, with special additions from the course in architecture, and special instruction in drainage, water supply, sewerage, heating, and ventilation, dangerous trades and occupations, vital statistics. sanitary jurisprudence, the principles and practice of municipal hygiene, microscopy and biology.

Hygiene.—The object of this course is to give such instruction as to the laws of life and health, the structure of the human body, the general principles of hygiene, first help in accidents and injuries, etc., as should be possessed by every well-educated professional man.

The instruction is given by lectures and recitations during the second year. The lectures are illustrated by diagrams and models.

Microscopy and Biology.—Practical instruction in the use of the microscope is given. Laboratory instruction for four hours each week is given throughout the second and third years and lectures in each session of the third year.

The biological laboratories are supplied with all apparatus required for microscopical manipulation and for those branches of biological study needed in sanitary investigation. A separate culture-room has been fitted up for bacterial examinations.

The general course of study is indicated in the following scheme :—

Microscopy.—Stand, its construction, use, care, and choice; simple lens, optical principle, construction, and use; compound lens, low-power objectives, use, and care; accessory apparatus, general; method of work, illumination, effect of different media; the eyes, peculiarities, use, and protection; drawing, free-hand and with camera lucida; micrometry, preparation of table; magnification, preparation of table; mounting, dry, in liquid and in cells; section cutting, soft and hard tissues, crystals, rock sections, and grains; staining; high-power objectives, use and care, cover-connections, and immersion fluids; accessory apparatus, special; micro-chemistry and microspectroscopy; micro-mineralogy and microlithology; adulteration of foods, etc., detection; fibres and handwriting; photomicrography.

Biology.—Laboratory examination of unicellular forms of life: yeast; protococcus; amœbæ; bacteria; the moulds (mucor and penicillium); the anatomy of the clam; anatomy of the lobster; anatomy of the frog; biological analysis of natural waters; biological analysis of air; biological examination of disinfectants.

Books of Reference.—The Microscope, W. B. Carpenter; How to Work with the Microscope, L. Beale; Elementary Biology, Huxley and Martin; Micro-organisms and Disease, Klein; Bacteriology, Crookshank and Hueppe; Photomicrography, Sternberg.

Geodesy and Practical Astronomy.

Instruction in geodesy and practical astronomy during the third year embraces:

1. A course of general lectures on astronomy, fully illustrated by lantern views.

2. Lectures on Geodesy.—General outlines of geodesy; description and illustration of the different kinds of triangulation, primary, secondary, and tertiary; description of the United States Coast Survey primary base apparatus; description of the United States Coast Survey secondary base apparatus; measurement of subsidiary base lines; reconnoissance surveys; stations and signals; observing tripods and scaffolds; station marks, underground and surface; observation of angles; instruments, direction and repeating; application of Legendre's theorem to the solution of spheroidal triangles; records and computations; latitude, longitude, azimuth, and time observations and computations.

3. Practical use, in the observatory, of the transit instrument for time and zenith telescope for latitude, and in the field, use of the sextant, and reflecting circle for time, latitude, and longitude approximations.

During six weeks of the summer vacation, at the close of the third year, the students in civil engineering are required to make a geodetic survey of some region.

Instruction in geodesy is continued in the fourth year by lectures and use of instruments; spirit levelling; trigonometric levelling; magnetic determinations; figure of the earth; theory of astronomical instruments.

Architecture.

During the first and second years, the time which is given in other courses to laboratory work is in this course given to architectural drawing. This is so laid out as to include exercises in the ordinary processes of draughtmanship, the making of plans, elevations, sections, and details, both on a large and on a small scale; using pencil and

pen, brushes and colors, with auxiliary exercises in tracing and sketching. The examples are so chosen as to make the student familiar with the commonplaces of architectural form, and are accompanied by lectures upon the elements of architecture, in which the forms and proportions of the Greek and Roman Orders, of doors and windows, arches, staircases and balustrades, domes and vaults, roofs and spires, are set forth, and the best ways of drawing them explained. These lectures and exercises are supplemented by special courses on perspective, and on shades and shadows. At the same time a series of illustrated lectures is given upon Egyptian, Assyrian, Greek and Roman architectural history.

During the second year the students of architecture complete their elementary studies in mathematics and chemistry, following at the same time the work in descriptive geometry and stone-cutting, given in the department of engineering, and a portion of the work in geology.

Besides the lectures upon hygiene and kindred topics which are given to the entire third class, a special course upon sanitary engineering is given to the students of architecture. This course covers, in the third year, the drainage of buildings, including the arrangement of pipes and fixtures, the disposal of household refuse, and the drainage of cellars and grounds. During the fourth year, the ventilation and warming of buildings is taken up, and dicussed from both the practical and the scientific point of view.

In the third and fourth years the study of scientific construction is pursued in connection with the classes of engineering, most of the time, however, being given to strictly professional work. This is for the most part taken by the two classes in common, one class taken up in their fourth year what the next class takes in the third, and *vice versa*, the whole thus forming a single two years' course. These studies are arranged under four heads :

I. Under the head of history, the architecture of the middle ages is taken up in one year, and that of the renaissance, and its more modern derivatives, in the next. On completing the study of ancient architecture, then, in the second year, one class goes on directly to that of the middle ages of the third year, and to that of the renaissance in the fourth. The next class passes at once from ancient classical architecture to modern, finishing with the mediæval styles.

During the first half of the year the ground is gone over in a course of lectures, and it is reviewed during the second half of the year, the class preparing a series of reports with illustrative drawings.

II. Under the general head of ornament, etc., is comprised the study of the decorative details of the different architectural styles, and of the contemporary forms in other branches of art, especially the decorative arts employed in building. The materials and processes employed in these arts, and the theory of æsthetics, in form and color, come under this head.

III. Under the head of architectural practice comes the study of specifications and working drawings, so far as they can profitably be studied in such a school, and of the materials and processes employed in building operations. It is proposed that a special architectural laboratory shall afford opportunity for the study of oils and paints, cements, mortars, etc., and of testing their quality.

IV. Under the head of drawing and designing is comprised the practice of original composition in the working out of problems in design, from given data, as well as further exercises in draughtmanship, both free-hand and with the pencil, pen, or brush, illustrating the study of the special topics enumerated above. A laboratory is provided with facilities for modelling in clay or wax, and for working in plaster.

The subjects of the problems given out last year were :

1. A group of vases.
2. An iron gate.
3. The second story and side elevation of the Casino of the Giustiniani Villa, the first-story plan and front elevation being given.

4. The second story and front and rear elevations of a small Roman palace, the first-story plan being given.

5. The Farnesina Villa, from notes and memory.

6. An open portico.

7. The pedestal for a statue, the photograph of the statue being given.

8. The same, revised and put into perspective with full-size details.

9. To describe a building in writing, from a photograph.

10. To draw out the elevation of a building, from such a written description.

11. A small museum, with three rooms in one story.

12. A theological school, in two stories, with a chapel.

The students give a certain proportion of time to exercises of a critical and literary character, designed to practise them in both reading and writing. During the first two years French text-books are read in the class.

Besides the excellent provision in the college library, the department has a special collection of books and drawings, and about twelve thousand photographs.

Memoirs, Projects and Dissertations.

The following memoirs, projects and dissertations required from students of the several classes of the year 1887-8, are given simply to illustrate the kind of work required by the by-laws.

Students of the second class in all the courses, except those in architecture, were required to hand to the instructor in drawing, on or before October, 10, 1887, six drawings, as follows :

No. 1. Landscape. Free-hand pencil sketch.

No. 2. Iron bridge. Free-hand pencil sketch.

No. 3. Staircase. Free-hand pencil sketch.

No. 4. Steam pump. Free-hand pencil sketch.

No. 5. Freight waggon. Right line orthographic scale drawings in ink, showing front and end views.

No. 6. Windlass. Right line orthographic scale drawings in ink, showing front and end views.

Course in Mining Engineering.

Students of the fourth class were required to hand to the professor of engineering on or before October 10, 1887 :

A memoir upon some topic assigned to each member of the class in connection with the summer school in practical mining.

Students of this class were also required to choose, for a graduating thesis or project, a subject in geology, in metallurgy, or in engineering, and to hand the thesis or project to the professor of geology, the professor of metallurgy, or the professor of engineering, on or before May 2, 1888.

Course in Civil Engineering.

Students of the fourth class were required to hand to the professor of geodesy, on or before October 10, 1887, memoirs upon topics, assigned to the students individually, on subjects taught in the summer school of practical geodesy.

The students of this class were also required to hand to the professor of engineering, on or before May 2, 1888, a project or thesis on one of the following subjects, viz. :

1. A project for the supply of water to a town, including reservoirs, conduits and all appliances for distribution.

2. A roof of not less than 180 feet span.

3. A bridge of not less than 250 feet span.

4. Design for the sewerage and surface and subsoil drainage of a town of not less than 10,000 inhabitants.

5. The heating and ventilation and drainage of a large public building.

The choice of one of these subjects was made during the summer, and such knowledge of the subject chosen as was practicable, gained during the vacation by examination of existing works.

The details of the projects or theses were then given to the students at the beginning of the first session after the summer vacation.

Course in Metallurgy.

Students of the fourth class were required to hand to the professor of engineering, on or before October 10, 1887, memoirs on subjects studied in the summer school of practical mining.

Students of this class were also required to hand to the professor of metallurgy, on or before May 2, 1888, one of the three following projects :

Metallurgical Project.—An establishment to produce 300 tons of pig-iron per day. The furnace will be located east of the Mississippi River. The ore will be composed of hematites and limonites, the hematites yielding 60 per cent. of sesquioxide of iron, 0.055 per cent. of sulphur, and 0.065 per cent. of phophorus. The limonite will contain 50 per cent. of sesquioxide of iron, and be equally pure. The fuel and fluxes will be such as can be had most readily in the district selected. The air will be heated by a regenerative system of ovens. The furnace will have a closed front, and the charges be made mechanically.

Or, an establishment to make 350 to 400 tons of open hearth steel per week from material purchased. The establishment will be located within ten miles of New York City. with a water front and docks for water transportation, and a railway for inland transportation. All the material used, as well as the fuel, will be purchased in the open market. None of the metal produced will be sold in ingots; it will all be manufactured for the market, the rolling mills for the manufacture being included in the plant.

Or, an establishment to produce and desilverize 10,000 tons of lead bullion, containing on an average 150 ounces of silver and 2 ounces of gold to the ton. The establishment will be located in or west of the Rocky Mountains. The ore will be composed of earthy carbonates, with some galenite, anglesite and cerussite, and will contain 25 per cent. of lead, 25 per cent. of silica, 25 per cent. of sesquioxide of iron, and 1 per cent. of sulphur. The fuel and fluxes will be such as can be most readily had in the district selected.

The projects will comprise memoirs, estimates and drawings.

Course in Geology and Palæontology.

Students of the third class were required to hand to the professor of geology, on or before November 1, 1887, a memoir on one of the following subjects :

1. Notes on the flora or fauna of any geographical district visited.

2. Observations on the structure, distribution and habits of any of our fresh-water fishes.

3. Catalogues and collections of mollusks inhabiting any lakes, rivers or districts.

4. Notes on the economy of observed insects.

5. Notes on the various observed methods by which the seeds of plants are distributed.

Students of the fourth class were required to hand to the professor of geology, on or before November 1, 1887, a memoir on one of the following subjects :

1. Report on the geology of any district visited—embracing : (*a*) topographical features and their causes ; (*b*) surface geology ; (*c*) sections of strata with lithological character, thickness, dip, strike and fossils of each bed ; sketches of rock outcrops ; (*d*) suits of specimens of rocks and fossils, rocks 3x4x1 inches.

2. Report on any special formation which may be examined—embracing : (*a*) the geographical area of its outcrops ; (*b*) its mineral character and origin of the material composing it ; (*c*) sets and collections of its fossils ; (*d*) reading of the history of its deposition.

3. Report on any examined deposits of ore or other useful minerals, as : (*a*) the magnetic iron ores of New York and New Jersey, phenomena and history ; (*b*) the limonite ores of the Alleghany belt, character of deposits and age ; (*c*) the zinc ores of Franklin and Friedensville ; (*d*) the chromic iron of the Alleghany belt, where and how it occurs.

And on or before May 2, 1888, a dissertation on one of the following subjects :

1. The mesozoic sandstones of New Jersey and the Connecticut valley ; their geological phenomena, history and relations to the associated trap rocks.

2. The limonite ores of the Alleghany belt ; their phenomena, age and origin, *i.e.*, where and how they occur, when and how they were deposited.

3. Eozoon Canadense ; is it organic ?

Course in Analytical and Applied Chemistry.

Students of the third class were required to hand to the professor of chemistry, on or before November 1, 1887, a memoir on one of the following subjects :

1. Aluminium.

2. The essential oils : their occurrence, chemical composition, preparation and uses.

3. Nitric acid and nitrates ; nitrous acid and nitrites : their occurrence in nature, formation, detection, estimation and functions.

4. Chloral hydrate and allied bodies : their nature, formation, properties and uses.

The memoir must contain full references to authorities throughout the text, a table of contents, a chronological bibliography and an index.

Students of the fourth class were required to hand in to the professor of chemistry, on or before November 1, 1887, a memoir on one of the following subjects :

1. The different kinds of glucose and sugar, with special reference to their occurrence, formation, detection and estimation.

2. Methods for the chemical examination of alcoholic beverages, including simple analysis and the detection of adulterations.

3. Peruvian bark ; with methods for its analysis.

4. Alkalimetrical indicators.

The memoir must contain full references to authorities throughout the text, a table of contents, and an index.

And on or before May 2, 1888 :

A thesis on the work of the fourth year in the organic laboratory.

Course in Architecture.

Students in this course were required to hand in to the Professor of Architecture, on or before the second Monday in October, 1887, one hundred sketches, with an accompanying memoir. These drawings were executed with the pencil or with the brush, or

both, and were made either from prints and drawings, or from the object, or from nature. They were either in outline or shaded, in black and white or in color, and they were to represent, among other things, the plans, elevations, and perspective view of a small building, with details of framing and other particulars of construction, when access could be had to buildings in course of erection, and, in any case, were to include large scale drawings of bases, cornices, and mouldings. A plan, section, two elevations, and a perspective of every object, large or small, and the dimensions, at least approximate, were desired. The date at which the sketch was made and the time occupied in making it were written upon each, and they were mounted upon sheets of paper or cardboard, fifteen inches by twenty-two, one or more upon each. The drawings were mostly made in large-sized sketch books on one side of each leaf, so that they might be cut out and thus mounted. The memoirs stated from what the sketches were taken, pointing out anything of interest that had been observed, in respect either of construction or of design.

Students were advised to spend a part of the vacation in an architect's office, and were furnished with the proper letters of introduction by the Professor of Architecture. Every day spent in an office was taken in lieu of a sketch. They were also desired to read as much French and German as possible during the summer, and were advised to subscribe to a French or German newspaper.

Students of the second class, also, during the vacation, prepared lists of the chief persons and most important events mentioned in Greek and Roman History from 1,000 B.C. to 500 A.D., making outline maps, drawn or traced, showing the principal countries and cities. Students of the third and fourth classes did the same with Modern History for the last five hundred years, using any historical works covering these periods that furnished sufficient data, as a preparation for their studies in the history of architecture.

TEXT-BOOKS.

(The text-books required by the first and second classes are named in connection with the subjects in the synopsis of studies.)

Books preceded by an asterisk (*) are optional—the others are indispensable.

Third Class.

Peck's Analytical Mechanics.
Peck's Popular Astronomy.
Davies' Surveying (revised edition).
*Publications of the U. S. Coast and Geodetic Survey, relating to the fundamental geodetic operations.
*Davis's Formulæ for Railroad Earthwork.
Searle's Henck's Field-Book for Engineers.
Gillmore's Roads and Pavements.
Stony's Theory of Strains.
Rankine's Civil Engineering.
*Mahan's or Wheeler's Civil Engineering.
Rankine's Machinery and Mill Work.
*Callon's Lectures on Mining.
Egleston's Tables of Weights, Measures, Coins, etc.
Egleston's Metallurgical Tables.
*Kerl's Metallurgy.
Rickett's Notes on Assaying, and Assay Schemes.
Cornwall's Blowpipe Analysis.
Plattner's Blowpipe Analysis.
Cairns' Quantitative Analysis.

Johnson's Fresenius's Quantitative Analysis.
Wagner's Chemische Technologie.
Dana's Manual of Geology.
Nicholson's Palæontology.
Von Cotta and Lawrence's Rock's.

Fourth Class.

*Text-book of Least Squares, by Merriman.
*Wright's Treatise on Adjustment of Observations.
*Clarke's Geodesy.
*Helmert's Mathematischen und Physikalischen Theorieen der Höher. Geodäsie, two volumes.
*Jordan's Vermessungskunde, two volumes.
*Doolittle's Practical Astronomy, as applied to geodesy and navigation.
*Publications of the U. S. Coast and Geodetic Survey, relating to the fundamental geodetic operations.
Henck's Field-Book for Engineers.
Greene's Graphical Statics.
Weisbach's Mechanics of Engineering.
Rankine's Civil Engineering.
Rankine's Prime Movers.
Rankine's Machinery and Mill Work.
Rigg on the Steam-Engine.
Goodeve on the Steam-Engine.
*Welsh's Designing Valve Gearing.
Latham's Sanitary Engineering.
Sewers and Drains for Populous Districts, by J. W. Adams.
Fanning's Water-Supply Engineering.
Stevenson on Canals and Rivers.
Stevenson on Harbors.
Parson's Manual of Permanent Way.
*Colyer's Hydraulic Lifting and Press Machinery.
*Röntgen's Thermodynamics, Du Bois' translation.
*Planât on Warming and Ventilation.
*Joly, Warming and Ventilation.
Callon's Lectures on Mining.
*Burat's Exploitation des Mines.
*Lottner's Bergbaukunst.
*Rittinger's Die Aufbereitungkunde.
*Gaetschman's Aufbereitung.
*Cotta's Treatise on Ore Deposits, by Prime.
Page's Economic Geology.
Burat's Géologie Appliqué.
D'Orbigny's Palæontologie Élémentaire.
*Whitney's Metallic Wealth of the United States.
Egleston's Metallurgical Tables.
Egleston's Metallurgy of Gold, Silver, and Mercury.
*Kerl's Probirkunst.
*Allen's Introduction to the Practice of Commercial Organic Analyses.
*Berthelot's Leçons sur les Methodes Générales de Synthèse en Chimie Organique.
*Berthelot et Jungfleisch's Traité Élémentaire de Chimie Organique.
*Roscoe and Schorlemmer's Treatise on Chemistry (Organic Chemistry).
*Strecker's Short Text-book of Organic Chemistry, by Wislicenus.
*Beilstein's Handbuch der Organischen Chemie.

LIBRARY.

The library is open to all officers, students, and graduates, both for borrowing and reference, daily, except Sundays and Good-Friday, throughout the year, including all holidays and vacations.

It now contains 84,000 carefully selected volumes, and additions are constantly made of the best books in all departments, especially of expensive and costly works not readily accessible elsewhere. In addition, the library of the New York Academy of Sciences is on deposit in the library rooms, and is accessible to readers. More than 500 different serials, including the leading transactions of societies, periodicals, etc., in all languages, are regularly received, and special effort is made to provide for immediate use, without the formality of asking, the best reference-books in all departments—dictionaries, encyclopædias, indexes, compends, etc.

Besides the regular author and title catalogues, there are a minute subject-classification on the shelves; a complete subject-catalogue, in a separate book for each class; an exhaustive card-catalogue, with analyses and notes for readers; and a very full printed index of topics. To all catalogues, indexes, and other aids and guides, all students have unrestricted access, day and evening.

A pamphlet giving fuller information about books, building, catalogues, and the privileges accorded to readers, will be mailed on application to the chief librarian.

CABINETS AND COLLECTIONS.

Collections of specimens and models, illustrating all the subjects taught in the school, are accessible to the students, including:

- Crystal models.
- Natural crystals, pseudomorphs.
- Ores and metallurgical products.
- Models of furnaces.
- Collection illustrating applied chemistry.
- Fossils.
- Economic minerals.
- Rocks.
- Olivier's models of descriptive geometry.
- Models of mechanical movements.
- Models of mining tools.
- Models of mining machines.
- Casts, antique statuary, animals, etc.

Crystal Models—The lectures on crystallography are illustrated by a collection of 150 models in glass, which show the axes of the crystals and the relation of the derived to the primitive form. This suite is completed by 400 models in wood, showing most of the actual and theoretical forms, and also by a collection of natural crystals showing the forms as they actually occur in the prominent mineral species.

Minerals—The cabinet of minerals comprises about 30,000 specimens, arranged in cases. It includes a large suite of pseudomorphs, a collection illustrating the physical characters of minerals, and a collection illustrating crystallography by natural crystals, showing both their normal and distorted forms. The minerals are accompanied by a large collection of models in wood showing the crystalline form of each. Arranged in wall cases are large specimens, showing the association of the minerals. There are also three separate student collections of average specimens, amounting in the aggregate to over 6,000 specimens.

Ores and Metallurgical Products—A very complete collection of metallurgical products, illustrating the different stages of the type process in use in the extraction of each metal in this country, and in Europe, is accessible to the students. The collection is constantly increasing. Most of the specimens have been analyzed and assayed.

Models of Furnaces—An extensive collection of models of furnaces has been imported. A very large number of working drawings of furnaces and machines used in the different processes is always accessible to the students.

Applied Chemistry is illustrated by several thousand specimens of materials and products arranged in a cabinet of industrial chemistry for exhibition at the lectures and for inspection by the students.

The Geological Collection consists of over 100,000 specimens (to which additions are constantly made), forming the following groups:

1st. A systematic series of the rocks and fossils characteristic of each geological epoch, numbering over 70,000 specimens.

2nd. A collection of ores, coals, oils, clays, building materials, and other useful minerals, illustrative of the course of lectures on economic geology, and believed to give the fullest representation of our mineral resources of any collection yet made.

3rd. A collection of 5,000 specimens of rocks, and the minerals which form rocks, to illustrate the lectures on lithology.

4th. A palæontological series, which includes collections of recent and fossil vertebrates, articulates, mollusks, radiates, and plants. In this series is to be found the largest collection of fossil plants in the country, including many remarkably large and fine specimens, and over 200 species of which representatives are not known to exist elsewhere. Also, the most extensive series of fossil fishes in America, including among many new and remarkable forms, the only specimens known of the gigantic *Dinichthys;* a suite of Ward's casts of extinct saurians and mammals; fine skeletons of the great Irish elk, the cave bear, the New Zealand moas, *ichthyosaurus, teleosaurus,* etc.

5th. Several hundred maps and diagrams illustrating the course of instruction; lanterns, microscopes, and over 2,000 slides to be used with them.

Drawing Models—There are, for the use of students, a large collection of flat models and of plaster casts; the Olivier models, forming all mathematical surfaces by silk threads, and admitting of a variety of transformations; also other models, illustrating general and special problems of descriptive geometry, shades and shadows, and stone-cutting; photographs of plaster casts and of parts of machines, for use in free-hand drawing; drawings of machines and parts of machines for studying and copying; also, landscapes in crayon and in water-color for instruction in sketching; models of mining machines and mining tools, stationary steam-engines, single and double cylinders, sections of steam-cylinders, water-wheels, turbines, shaking tables, stamps, crushers, blowing machines, pumps, etc.

Surveying Instruments—For the use of the students of the summer school of surveying there is a collection of instruments sufficient for over thirty surveying squads, comprising transits, levels, and plane tables by Heller & Brightly, Buff & Berger, Stackpole, and other makers; also compasses, dipping needles, hand levels, water levels, odometer, tapes, chains, level rods, telemeters, sight poles, and tents, and camp equipage.

Civil Engineering is illustrated by a collection of models of beams, beam joints, roof and bridge trusses, masonry, doorways, arches, walls, culverts, bridges, and canal locks; working models of overshot, breast, undershot, and different kinds of turbine water-wheels; a machine, made by Fairbanks & Co., for testing the strength of materials; a five-inch condensing steam-engine, with a stroke of six inches; horizontal, vertical and sectional steam-engines and valves, etc.

A complete working model, full size, of the Westinghouse automatic train-brake has been recently added, and a series of injectors for feeding boilers. Also models, full size, of air and gas machines.

There have been recently added to the department of engineering, for the use of students in geodesy, two four-metre compound bars with Borda's scales, etc., for measuring base line; one standard four-metre bar; one eight-inch theodolite with horizontal and vertical circles for measuring horizontal angles and double zenith distances.

Mining Engineering is illustrated by models of blowing engines, ventilators, mine shafts, tunnels, galleries, methods of walling, methods of tubbing shafts, methods of measuring shafts, shaft house, hoisting engine, safety cages, man-engines, ladders, shaking tables, washers, stamps, crushers, mining machines, lamps and tools, artesian well-borer, blasting apparatus, etc.

Additions to the various collections are constantly made.

ASTRONOMICAL OBSERVATORY.

The astronomical observatory contains a set of portable astronomical instruments ; a forty-six inch transit, by Troughton and Simms ; a combined transit and zenith instrument for time and latitude determinations ; an equatorially mounted refractor of five inches aperture, to which is attached a spectroscope with the dispersive power of twelve flint-glass prisms of fifty-five degrees, by Alvan Clark ; also a diffraction spectroscope with grating, by L. M. Rutherford, Esq.

A set of comparison apparatus, with electrodes, Plucker's tubes, coils, etc, accompanies the spectroscope.

Instruction in practical astronomy is given in the observatory to students of the third and fourth classes in the course of civil engineering.

By the gift of Mr. Rutherford there have been added to the observatory equipment : (1) An equatorial refracting telescope of thirteen inches aperture, supplied with a correcting lense for photographic work. With this instrument belong two micrometers for position measurements. (2) A transit instrument of three inches aperture by Stackpole & Brother. (3) A Dent sidereal clock. (4) A micrometer for measuring photographic plates, and sundry other pieces of apparatus. These gifts of Mr. Rutherford increase the value of the instruments in the observatory by about $20,000. The observatory has a fine mean-time clock by Howard & Co., also a chronograph by Fauth & Co., a personal equation machine, etc. The observatory is lighted by electricity.

STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, NEW JERSEY.

Founded by Edwin A. Stevens.

The Faculty of this Institute consists of eleven professors and three assistant professors, as follows :—

Henry Morton, Ph.D., President.
Alfred M. Mayer, Ph.D., Professor of Physics.
De Volson Wood, A.M., C.E., Professor of Mechanical Engineering.
J. Burkitt Webb, C.E., Professor of Mathematics and Mechanics.
Charles W. MacCord, A.M., Sc.D., Professor of Mechanical Drawing.
Albert R. Leeds, Ph.D., Professor of Chemistry.
Charles F. Krœh, A.M., Professor of Languages.
Rev. Edward Wall, A.M., Professor of Belles-Lettres.
Coleman Sellers, E.D., Professor of Engineering Practice.
James E. Denton, M.E., Professor of Experimental Mechanics and Shop-work.
Wm. E. Geyer, Ph.D., Professor of Applied Electricity.
Thomas B. Stillman, Ph.D., Professor of Analytical Chemistry.
Adam Riesenberger, M.E., Assistant Professor of Mechanical Drawing.
Wm. H. Bristol, M.E., Assistant Professor of Mathematics.
D. S. Jacobus, M.E., Assistant Professor of Experimental Mechanics and Shop-work.

Plan of the Institution.

The plan of instruction, which has now been pursued for seventeen years, is such as will best fit young men of ability for positions of usefulness in the department of mechanical engineering, and in those scientific pursuits from which this and all the sister arts are daily deriving such incalculable benefits.

With this view there is afforded :

1. A thorough training in the elementary and advanced branches of Mathematics, and their application to mechanical constructions.

2. A systematic course in the theory of Machine Construction, and a study of existing systems.

3. The subject of Mechanical Drawing (which may well be called the language of engineering) receives much time and attention.

The course comprises the use of Instruments and Colors, Descriptive Geometry, Shades, Shadows and Perspective, and the Analysis of Mechanical Movements—the principles involved being at once and continuously applied in the construction of working drawings from measurements of machines already built, as well as in making original designs.

4. An extensive course of manual exercises in shop practice is combined with a course of experimental mechanics, to form a separate department, which aims to co-operate with the departments of engineering, mechanics and drawing, so as to bear to them the same relation as the physical and chemical laboratories do to the class-room work in physics and chemistry. Its courses, aside from the introduction of the student to the functions of tools, etc., are directly supplemental to the department of mechanical drawing, by familiarizing the student with the use of working drawings in the shop, and by the embodiment of the theoretical principles of mechanism in the form of exercises in gear cutting, etc., and directly supplemental to the departments of engineering and mechanics, by re-enforcing the apprehension of theoretical principles through the performance of exercises in the course of experimental mechanics.

5. Arrangements of an unusually perfect character have been made to give a thorough, practical course of instruction in Physics, by means of physical laboratories, in which the student is guided by the Professor of Physics in experimental researches bearing upon the subjects of his special study.

Thus the student will practise methods of making precise measurements of lengths, angles, volumes, weights, and time, and then apply these processes in the measurements of magnitudes relating to the Phenomena of Light, Sound, Heat, Electricity and Magnetism.

By this plan of instruction the knowledge of physical facts and laws is indelibly impressed on the mind of the student, while, at the same time, he is trained in methods of experimental investigation which will be of great value to him in the actual practice of his profession of Mechanical Engineer.

6. The subject of Chemistry is taught, chiefly by experimental lectures and demonstrations illustrative of its theoretical principles and of their application in the arts.

7. Analytical Chemistry, both Qualitative and Quantitative, is taught in the laboratories, where the students analyze the common minerals, metals, ores, slags, coal, furnace and illuminating gases, waters, etc.

8. The Spanish and German languages form an essential part of the course of instruction, since they are of practical value to the engineer and man of science in his professional work, and also afford that kind of mental culture which mathematical and physical science, if followed exclusively, would fail to supply.

8 The department of Belles-Lettres furnishes the means of cultivating literary taste and a facility in the graceful use of language, both in speaking and writing, which are as desirable in the engineer and man of science as in the classical student.

10. The subject of Applied Electricity is taught by means of complete appliances in the way of instruments for electrical measurements, dynamo machines, electric lamps and

the like, so as to fit graduates for responsible positions in connection with electric lighting and other similar companies.

The full course of the Stevens Institute of Technology occupies the period of four year, each year being divided into a Supplementary Term, during which the Sophomore, Junior and Senior Classes devote eight hours per day to the Department of Experimental Mechanics and Shop-work, and three regular terms.

Requirements for Admission.

Freshman Class.

No applicant under the age of seventeen years will be admitted to the examination, unless the Faculty be satisfied that he is able to bear the burden of the Institute course without detriment to his health, nor will any applicant under the age of seventeen be allowed to enter his class unless his examination shows proof of unusual proficiency.

The examinations will be on the following subjects :

Arithmetic.—The preparation should be especially thorough upon the properties of numbers, the operations in common and decimal fractions, the methods of finding the greatest common divisor, and the extraction of the roots of numbers.

Algebra.—Simple equations, theory of radicals, equations of the second degree, arithmetical and geometrical progression, permutations, binomial theorem, indeterminate co-efficients, logarithms, and series. Great importance is attached to a thorough knowledge and readiness in the solution of simultaneous equations of the second degree, and the reduction of radicals.

Geometry.—All of plane, solid and spherical geometry. The examination in this subject will be thorough, and the applicant must show a familiarity with all the fundamental geometrical forms and be able to demonstrate their properties and relations ; he should also be able to point out the most important ones.

Analytical and Plane Trigonometry.—The fundamental formulæ and their demonstrations, as well as the solution of plane triangles by means of natural and logarithmic tables will be insisted upon.

English Grammar.—The requirements are a practical acquaintance with the parts of speech, their relations, agreements, and government; the proper use of tenses and moods, the construction and arrangement of sentences.

On all these points we desire exact knowledge of the principles deduced from copious examples, and we attach no value to a minute knowledge of subtleties and exceptions. The latter properly belong to an advanced college course.

Geography.—The examination will be in the most important countries, cities, rivers, etc., most frequently occurring in the perusal of the daily newspapers and in general history.

Composition.—An essay upon some topic assigned at the time of examination, and examined with reference to legible hand-writing, correct spelling, punctuation, and proper expression.

Universal History.—In the examination of Universal History but little prominence is given to dates. The questions relate to the great events ; their causes and effects. A conspicuous place is given in the questions to the History of the United States. Text-book—Barnes' General History and U. S. History, or Johnston's or Higginson's or Anderson's U. S. History.

Rhetoric.—The examination in Rhetoric will embrace all parts of the subjects which are contained in the text-books on Rhetoric. Text-book—Hart's Rhetoric.

French.—Beginning in September, 1888, applicants will be examined in French. The examination will be on translation from Knapp's Modern French Readings, the first half of the book, or from some equivalent.

Sophomore Class.

Mathematics.—The applicant will be required to give satisfactory evidence that he has studied all of the mathematical subjects required for admission, as well as those pursued during the first year of this course; after which he will be subjected to a special examination in Algebra and Analytical Geometry. The examination will test the applicant's knowledge of the subject, without reference to any particular author.

Mechanical Drawing.—Elementary Orthographic Projections.

Physics.—Parts of Deschanel's Physics, including Inductive Mechanics, Acoustics and Light.

Languages. — Krœh's Lectures on French Pronunciation, Collot's Pronouncing French Reader, Krœh's Regular and Irregular French Verbs, and translation of F. S. Williams' "Getting to Paris."

Belles-Lettres. — Entrance examinations: the English Language (Fowler's), and Deductive Logic (Jevon's), and Inductive Logic (Jevon's, and Lectures).

For the text books used in the Stevens High School write to Librarian for catalogue of same. It is not necessary, however, to be confined to those in the preparation.

Junior Class.

Mathematics.—The applicant will be required to show that he has studied all the subjects required in the previous part of the course, and sustain a special examination in the Differential and Integral Calcus, which will be sufficiently comprehensive to test the applicant's knowledge of algebra and analytical geometry.

Mechanical Drawing.—Church's Descriptive Geometry up to Perspective—Spherical Projections excepted.

Physics.—All of Deschanel's Physics; applicant must have attended experimental lectures on subjects contained in above work.

Chemistry.—A knowledge of general chemistry—organic chemistry not included. Text-books—Roscoe's Lessons in Elementary Chemistry and Fowne's Elementary Chemistry.

Analytical Chemistry.—Qualitative Analysis.

Languages.—Subjects required for Sophomore class, also Collignon's Les Machines, and a translation of some memoir from the Comptes Rendus of the French Academy of Sciences. Krœh's Pronunciation of German. Krœh's First German Reader. German Verbs, regular and irregular. Krœh's Die Anna-Lise, introduction and first two acts.

Belles-Lettres.—The entrance examinations. Fowler's English Language, Deductive Logic (Jevon's), Inductive Logic (Jevon's, and Lectures), and Shaw's English Literature. Chaucer. Spenser. Bacon, Shakespeare, two Dramas. Sprague's Milton's Paradise Lost. Pope's Essay on Criticism and Rape of the Lock. Byron's Childe Harold.

Senior Class.

Mathematics.—The applicant will be required to show that he has studied all the previous subjects in this course, and to sustain a special examination in Analytical Mechanics, of such scope as to test his knowledge on important mathematical and physical points.

Mechanical Drawing—All of Church's Descriptive Geometry—Spherical Projections excepted—and MacCord's Practical Mechanism.

Physics—Examination in Pickering's Physical Manipulations, or in the work of Kohlrausch on the same subject.

Engineering—Materials of Engineering, their properties and strength (Wood's and Thurston's); Valve Gearing (Zeuner); the Indicator (Hemingway); the Mechanism of

Engines, Furnaces and Boilers (Rankine's Prime Movers, chapters IV and V, Part III); Smith's Steam Making and Steam Using, or Goodeve on the Steam Engine, or Weisbach (Du Bois) on the Steam Engine, or Barr on Boilers; Machine Design (Unwin); Hydraulics, especially the flow of liquids in pipes and streams.

Chemistry—General Chemistry—Organic Chemistry not included—Metallurgy.

Analytical Chemistry—Examination in Qualitative Analysis and the quantitative estimation of the constituents of the following substances (or their equivalents) will be required; Iron ores, coal, pig iron or steel, furnace gases, paint ground in oil, and lubricating oils.

Books of Reference—Fenton's Qualitative Analysis, Fresenius' Quantitative Analysis' Allen's Commercial Organic Analysis, Troilius' Iron and Steel Analysis.

Languages—Requirements for Sophomore and Junior Classes, as given before, also translation of last three acts of Krœh's "Anna-Lise," and Huber's Mechanik.

Belles-Lettres—The entrance examinations and the requirements for the Sophomore and Junior classes as given herewith.

Students graduating in Academic departments of other colleges, and desiring to enter the Institute, are advised to examine our course, with a view to entering at the commencement of the Junior Year.

List of Text-Books.

Freshman Year.

Mathematics—Well's University Algebra; Wood's Plane and Spherical Trigonometry; Wood's Co-ordinate Geometry; Bowser's Differential and Integral Calculus.

Mechanical Drawing—MacCord's Lessons in Mechanical Drawing.

Languages—Krœh's Pronuncation of Spanish; Worman's First Spanish Book; Krœh's Selections from Contemporary Spanish Authors.

Physics—Deschanel's Natural Philosophy, Parts I and IV.

Belles-Lettres—Fowler's English Language; Jevon's Logic, Hill's Edition.

Sophomore Year.

Mathematics—Bowser's Differential and Integral Calculus; Wood's Analytical Mechanics.

Mechanical Drawing—Church's Descriptive Geometry; MacCord's Practical Hints for Draughtsmen.

Languages—Modern Spanish Literature, continued; Text-books not yet chosen; Krœh's Pronunciation of German; Krœh's German Verbs; Krœh's First German Reader; Krœh's Die Anna-Lise.

Physics—Deschanel's Natural Philosophy, Parts II and III.

Belles-Lettres—Shaw's English Literature; Morris' Chaucer; Spencer; Shakespeare; Bacon; Sprague's Milton's Paradise Lost, Books I and II., and Lycidas; Pope's Essay on Criticism and Rape of the Lock; Byron's Childe Harold.

Chemistry—Lectures, Roscoe's Chemistry.

Analytical Chemistry—Fenton's Qualitative Analysis.

Junior Year.

Mathematics—Wood's Analytical Mechanics; Rankine's Applied Mechanics.

Mechanical Drawing—Church's Descriptive Geometry; MacCord's Kinematics or Mechanical Movements.

Languages—Krœh's Die Anna-Lise ; Huber's Mechanik.

Engineering—Wood's Resistance of Materials ; Zeuner on Valve Gears ; Barr on Boilers ; Hemingway on the Indicator ; Unwin's Machine Design, Rankine's Prime Movers.

Chemistry—Bloxam ; Thurston's Materials of Engineering.

Analytical Chemistry—Books of Reference—Fresenius' Qualitative Analysis ; Allan's Commercial Organic Analysis ; Troilius' Iron and Steel Analysis ; Wanklyn's Water Analysis.

Senior Year.

Mathematics—Rankine's Applied Mechanics ; Burr's Bridges and Roof Trusses ; Wood's Roofs and Bridges.

Mechanical Drawing—MacCord's Kinematics or Mechanical Movements.

Engineering—Rankine's Prime Movers ; Wood's Thermodynamics ; Weisbach's (Du Bois) Mechanics of Engineering.

Degrees.

The Stevens Institute of Technology, as will be seen from its secondary title, and from the account of its general scope and plan of studies already given, is essentially a school of mechanical engineering, and will therefore confer upon its regular graduates the degree of Mechanical Engineer, when due evidence of proficiency has been afforded in the final examinations, and upon the presentation of theses, as described further on.

Expenses.

The fees for each year of the entire course, for instruction and the use of instruments, are one hundred and fifty dollars, for students at the time residing in the State of New Jersey. Those not so residing—*i. e.*, coming across the river each day from New York, or the like—are charged seventy-five dollars extra. This discrimination is made necessary by a clause in Mr. Stevens' will.

In the Chemical Laboratory each student will be supplied with a set of re-agent bottles, and an adequate quantity of chemicals and platinum vessels ; agate and steel mortars, etc., will be loaned to him from time to time, as his work may make their use necessary. With reference to other apparatus, he is at liberty to furnish himself from any dealer, or to borrow from the supplies of the school. At the end of each session he wiil be credited with those articles returned in good order, while the cost value of those destroyed will be deducted from the deposit.

A charge of five dollars per term will be made to each student for chemicals used in the laboratory.

In the Drawing Department each student will be expected to furnish his own instruments and materials.

In the Department of Shop-work the student will be expected to pay for the material used ; but the total cost for the entire course will not exceed sixty-five dollars.

The fees are payable in advance, at the beginning of each term.

In case of absence for more than half a term, on account of sickness or some unavoidable cause, one-half the fee will be returned, or credited.

Each student wi!! be required, on admission, to make a deposit of ten dollars to meet incidental expenses, such as those for drawing materials or special chemical supplies. This deposit can only be withdrawn when he graduates or leaves the Institute.

THE COURSE OF INSTRUCTION.

Synopsis of Studies.

First Year.

First Term.

Mathematics—Logarithms and Plane Trigonometry reviewed, with practical applications to engineering problems, Spherical Trigonometry.

Mechanical Drawing—Elementary Projections.

Languages—French.

Physics—General Properties of Matter; Inductive Mechanics.

Belles-Lettres—Fowler's English Language, Lectures, Essays.

Shop-Work.

Second Term.

Mathematics—Theory of Equations, Analytical Geometry and Calculus; Exercises in Mathematical Laboratory.

Mechanical Drawing—Elementary Projections.

Languages—Spanish.

Physics—Pneumatics, Laws of Vibratory Motions, and Acoustics.

Belles-Lettres—Deductive Logic.

Shop-Work.

Third Term.

Mathematics — Analytical Geometry and Calculus; Exercises in Mathematical Laboratory.

Mechanical Drawing—Elementary Projections.

Languages—Spanish.

Physics—Light.

Belles-Lettres—Inductive Logic.

Shop-Work.

Supplementary Term.

Shop-Work.

Second Year.

First Term.

Mathematics—Differential Calculus.

Mechanical Drawing—Machine Drawing from Sketches, Descriptive Geometry.

Languages—Spanish (concluded), German.

Physics—Heat and Meteorology.

Belles-Lettres—English Literarure.

Chemistry—Theoretical and General.

Analytical Chemistry—Qualitative Analysis, Laboratory Practice.

Shop-Work.

Second Term.

Mathematics—Integral Calculus.

Mechanical Drawing—Machine Drawing from Sketches, Descriptive Geometry.

Languages—German.

Physics—Magnetism and Electricity.

Belles-Lettres—English Literature.

Chemistry—Theoretical and General.

Analytical Chemistry—Qualitative Analysis, Laboratory Practice.

Shop-Work.

Third Term.

Mathematics—Integral Calculus, Applications.

Mechanical Drawing—Machine Drawing from Sketches, Descriptive Geometry.

Languages—German.

Physics—Electricity.

Belles-Lettres—English Literature.

Chemistry—Theoretical and General.

Analytical Chemistry—Qualitative Analysis, Laboratory Practice.

Shop-Work.

Supplementary Term.

Shop-Work.

Third Year.

First Term.

Mathematics—Analytical Mechanics.

Mechanical Drawing—Kinematics. Machine Drawing, Descriptive Geometry.

Languages—German.

Physics—Lectures on the use of instruments for making Precise Measures and on their applications to the practical work in the Physical Laboratory.

Chemistry—Metallurgy.

Analytical Chemistry—Qualitative Analysis, Laboratory Practice.

Engineering—The Steam Indicator, Foundations, Valve Gears, Link Motions and Mechanism of Engines.

Shop-Work.

Second Term.

Mathematics—Analytical Mechanics.

Mechanical Drawing—Kinematics, Machine Drawing, Descriptive Geometry.

Languages—German (concluded).

Physics—Lectures (see First Term.)

Chemistry—Metallurgy.

Analytical Chemistry—Quantitative Analysis, Laboratory Practice.

Engineering—Mechanism of Boilers, Lectures, Theory of Flexure and other Mathematical Properties of Materials, Foundations, Boilers.

Shop-Work.

Third Term.

Mathematics—Analytical Mechanics.

Mechanical Drawing—Kinematics, Machine Drawings.

Phsiycs—Lectures (see First Term.)

Chemistry—Metallurgy.

Analytical Chemistry—Quantitative Analysis, Laboratory Practice.

Engineering—Machine Design, Hydraulics.

Shop-Work.

Supplementary Term.

Experimental Mechanics.

Fourth Year.

First Term.

Mathematics—Construction; Adjustment and Use of Engineering Instruments; Graphical Statics; Problems in Applied Mechanics.

Mechanical Drawing—Machine Drawing and Design.

Physics—Laboratory Work.

Engineering—Thermodynamics, Heat Engines.

Applied Electricity—Lectures and Laboratory Work.

Analytical Chemistry—Elective.

Second Term.

Mathematics—Theory of Bridges and Roofs with Graphical Statics Applied; Selected Problems.

Mechanical Drawing—Machine Drawing and Design.

Physics—Laboratory Work.

Engineering—Steam Engines, Hydraulic Motors, including the Turbine.

Applied Electricity—Lectures and Laboratory Work.

Analytical Chemistry—Elective.

Third Term.

Work on Graduating Theses—Including Experimental Investigations and General Research.

Students of the Freshman and Sophomore classes require two to three hours, and students of the Junior and Senior classes three to four hours per day of study, in preparations for recitations called for by the above schedule.

Department of Mathematics and Mechanics.

These subjects will be taught in close connection, not only because such treatment is specially suitable for students of engineering, but also because mathematics has its deepest foundations in the mechanics of nature.

To this end trigonometry will be accompanied with practical applications to such engineering problems as will emphasize important formulæ and methods and impress them upon the memory. Such problems will be devised and executed with special reference to system and accuracy in obtaining data and in calculating results, and to give practice in the use of logarithmic and other tables.

In order that students may be thoroughly grounded in the fundamental facts and principles of Analytical Mechanics before commencing a mathematical treatment of the subjects, there will be a series of practical exercises, with models, in the Mathematical Laboratory, and these will be so arranged as to teach the student also the fundamental principles of Analytical Geometry and the Calculus in advance of the full treatment of those subjects in the class-room.

The following is the list of such portions of the exercises in the Mathematical Laboratory as have been already introduced into the course:

Exercise 1—Having given two tangents and one of the radii, to connect the tangent points with a compound railroad curve by the method of "deflection angles." Apparatus used—Plane, Table, Chain, Cross-Section Paper, Table of Tangents.

Exercise 2—Topographical Survey of a field and graphical estimation of area. Apparatus used—Plane, Table, Chain, etc.

Exercise 3—Compass Survey of field and numerical calculations of area, using principles of co-ordinate geometry. Apparatus used—Compass, Chain, Trigonometric Tables.

Exercise 4—Profile of line. Apparatus used—Level, Rod, Chain.

Exercise 5—To determine elevation of a point, with corrections for instrumental errors. Apparatus used—Level, Rod.

Exercise 6—To determine experimentally the condition of equilibrium of a number of forces.

Exercise 7—To determine experimentally the relation between the moments of forces in equilibrium.

Exercise 8—To determine experimentally the centre of gravity of several bodies.

Exercise 9—To determine the moment of inertia of a body by means of the torsion pendulum and standard units of mass.

Exercise 10—To find the moving force in the torsion pendulum.

Exercise 11—To determine the stresses in several models of link work.

Exercise 12—To determine the mass of a body by means of a "false balance" and units of mass.

Exercise 13—To determine experimentally the resultant of two rotations in space.

Department of Physics.

This department offers the students every facility for the acquisition of a thorough knowledge of physics.

During the first year the first term is given to the study of the general properties of matter and to inductive mechanics; the second term to pneumatics and to the laws of vibratory motions and acoustics; the third term to light.

In the second year the first term is occupied in the study of heat and meteorology; the second and third terms are spent in the study of magnetism and electricity.

During the third year the Professor of Physics delivers lectures on the modes of making precise measures. He shows the application of these measures in the various departments of physics, and explains the construction, the methods of adjustment, and the manner of using instruments of precision.

The fourth year the student spends in the physical laboratories, pursuing experimental investigations, schedules of which are prepared for him by the Professor of Physics.

To give an idea of the character and scope of this work, we here cite some of the investigations at which the student works during the senior year.

The use of measuring instruments which employs the vernier, micrometer screw, micrometer microscope, and divided circle; the construction of linear scales and divided circles on the linear and circular dividing engines; the comparison of the lengths of the standard yard and meter; determinations of the co-efficients of expansion of solids and liquids; the testing and correction of thermometers; the determination of the specific heats of various solids and liquids; calorimetry, as applied to the determination of the heat producing powers of various fuels; also the use of pyrometers and the various means available for determining the temperatures of furnaces and like highly heated spaces. Practice in photometry. The measurement of the angles of crystals and of prisms with

the reflecting goniometer and spherometer, and the determination with the latter instrument of the wave lengths of a few of the rays of the spectrum. Methods of measuring the indices of refraction of substances, of determining the focal lengths and magnifying power of lenses, and the use of instruments, such as the saccharometer, involving the employment of polarized light. The plotting of a map of part of the spectrum.

In the organization of the Department of Physics, two objects were sought: First, to give thorough instruction to the students by means of lectures, fully illustrated by experiments, and by recitations on general physics, followed by practical experimental work in the physical laboratory; and, secondly, to advance knowledge in this department of science by original researches, conducted by the Professor of Physics. This mode of work has been of eminent service to the student, by causing a lively interest in his studies, as he verifies and extends, by his laboratory experiments, the knowledge which he had previously derived from lectures and text books.

The extensive cabinet of instruments which the Institute possesses affords the student advantages which are nowhere excelled.

Books of Reference—Kohlrausch's Introduction to Physical Measurements; Pickering's Elements of Physical Manipulations; Glazebrook and Shaw's Practical Physics—D. Appleton & Co, N. Y., 1885; Stewart and Gee's Lessons in Elementary Practical Physics—MacMillan & Co., London, 1885.

Department of Mechanical Drawing.

In the organization of the Department of Mechanical Drawing, the object aimed at is to make the course of instruction thorough, practical, of direct utility, and comprehensive.

The requirements of many of the industrial arts at the present day are such as to necessitate the delineation, not only of what already exists, but of what is yet to be made. Both demand a knowledge of the science of drawing, and the latter especially involves a certain exercise of the imagination, in order to form clear physical conceptions of the particular design in contemplation, not only in regard to its appearance as a whole, but as to the relations and proportions of its parts.

This ability to form a vivid and distinct mental image, as well as to fix it permanently by accurate representations, though useful to all, is more emphatically so to the Mechanical Engineer, who is daily called on, not to copy what has been done, but to do what has not been.

These considerations have been kept distinctly in sight in the conduct of this department. The matter taught and the method of teaching have been selected with a view of giving the student a firm grasp of principles, of developing and strengthening his imaginative power, and giving him direct practice in the application of both. The course adopted to attain these ends may be briefly outlined as follows:

The foundation is laid by practice in the simple drawing of lines, in order to acquire facility in the manipulation of the instruments. The exercises selected are such as will be of subsequent use, arranged in a progressive order, beginning with geometrical constructions involving straight lines and circular arcs only, and ending with the more complex curves, such as the ellipse, helix, epicycloids, etc. Attention to symmetry, proportion and arrangement is enforced from the first, the diagrams not being copied, but constructed.

Elementary studies of projection are then taken up, the method adopted being that of beginning by making the drawings of a solid object bounded by plain surfaces, such as a prism, in various positions, and proceeding by degrees to the similar treatment of more complex forms. The relation between the drawing and the thing drawn is more easily grasped at first, when the latter is not a mere abstraction, like a line or plane in space, but a definite and tangible object; and when the subject is presented in this manner, no difficulty is experienced with the simpler problems of intersection and development, which not only bring the imaginative faculty into play, but afford practical exercises of great utility.

The next step is to the drawing of parts of machines from actual measurements. The student is at once set to work as a draughtsman. A part or a whole of some piece of

mechanicism is assigned to him, which he is to study, to measure, to sketch, and finally to draw, the requirements being exactly as if he were employed in the drawing office of an engineering establishment, that he shall produce complete working plans, from which the original could be replaced were it destroyed. He thus acquires some knowledge of details, and is taught to observe closely, while at the same time his previously acquired skill and information are practically applied.

Simultaneously with this, Descriptive Geometry is taken up as an abstract science; not as an ultimate object, but its practical application being always kept in view, it is made a means to an end, and that end is the acquirement of such a mastery of the principles of drawing, that the student shall be able to cope with any problem when it arises in the course of his practice. The identity of the operations with those of Mechanical Drawing is never lost sight of, and the problems are frequently put in a practical form. This is not done exclusively, however, because they afford, in the abstract, the best possible exercise of the imaginative power. The study is continued in application to Shades and Shadows, and to Linear Perspective, in connection with which the principles of Aerial Perspective, as applied to the shading of mechanical objects, are explained, and a little time is given to practice in the execution of finished drawings. But the ability to make elaborately shaded pictures is regarded as the least valuable of the qualifications of a mechanical draughtsman. However great his skill in this way may be, the accomplishment will save him but little in his professional career if it be acquired at the expense of accuracy, or facility in the construction of working plans. Therefore, while it is designed to impart a thorough understanding of the principles involved in making such drawings, comparatively little time is devoted to their practical execution.

The mechanical engineer plans machines, and these move; consequently the study of the laws of their motions is an important branch of his education; and it is properly given a place in this department, since to make the drawings of a piece of mechanism implies the making of them so that each part shall move in harmony with the rest, and the depth of engineering disgrace is reached when, through any oversight, one part interferes with another. This study might, also, especially when the more complicated mechanical movements are considered, be regarded as a branch of applied mathematics of the higher order. But, however these laws may be investigated, this fact remains: that for the purpose of the draughtsman the results must be translated into his language, and expressed in graphic form—the ways of the analyst are not his ways, and the algebraic formula must be replaced by a diagram. Fortunately, however, the investigations may be made. at least as applied to by far the larger and more important part of the motions with which he has to deal, in his own language and by his own methods. In this part of the course, therefore, the Geometry of Mechanism is taught by graphical construction alone, practical exercises in the plotting of mechanical movements, the drawing of the various forms of gearing, the construction of curves representing varied motion, and the like, being introduced from time to time.

Further, the course includes some practices in actual planning. A subject being assigned or selected, the student proceeds to work it up as though already engaged in the active pursuit of his profession; making first a skeleton diagram of the movement, and sketching in the proposed arrangement of parts, he calculates the strength and proportion of these, modifying the original plan when it is found necessary to do so by the results of these calculations, then making drawings of each part in detail, and finally a general plan of the completed design; a general supervision being exercised over the work while in progress, and hints and suggestions as to details and arrangement being made as occasion arises.

It should be stated, also, that much care is taken throughout the course to form the habit of correct judgment in determining what drawings to make of any subject in hand, and how to arrange them most advantageously. Written instructions in regard to this are exceedingly meagre, and yet it is a very important matter. The object is to show the workman what to make and how to make it; and experience proves that it is very easy to produce drawings which are perfectly correct, and yet do not clearly illustrate the objects represented. Nothing facilitates the operation of the mechanic more than to have a set of working plans which are clear, easily read, and connectedly arranged, and it is almost as

important that the draughtsman should know just what to draw as that he should be able to draw it well; from the first to the last, therefore, the student is taught the necessity of exercising his judgment in this direction, as well as care and forethought in all that he does.

Summarily, then, the object of the course is not merely to teach the student to read and write certain set phrases of the graphic language with ease and fluency, but to enable him to wield it with power and for a purpose. He is taught not so much to memorize as to compose; he is encouraged to think for himself, and to acquire vigor and facility by giving expression to new ideas; his practice during the course being made as nearly as possible to resemble that upon which he will enter at its close.

Department of Chemistry.

The material employed for purposes of instruction in this department, while embracing too great a variety of substances and apparatus to be particularly described, may be conveniently summarized under its most important heads.

First.—Apparatus for purposes of demonstration and for teaching, by means of lecture illustration, the principal topics of general and applied chemistry. This includes the various forms of apparatus designed by Hofmann and others for elucidating the doctrines of modern chemistry.

Second.—Materials for qualitative, volumetric, and quantitative analysis, including standard solutions and apparatus for the determination of weight and volume, which have been carefully calibrated and adjusted. As part of this material, should be mentioned, a cabinet of somewhat more than 3,000 specimens of the principal ores, minerals and rocks.

Third.—Instruments of precision employed in the graduation of eudiometers, the measurement of crystals, in the operations of gas, analysis, etc.

The study of chemistry is taken up at the beginning of the second year by instruction in the subject of chemical physics, in the laws of chemical combination, and in the principles involved in the determination of atomic and molecular weights. This is followed by the study of chemical notation and nomenclature, with practice in stoichiometry. Afterwards, the subject of chemical structure is taken up, along with an examination of the chemical and physical properties of bodies, as far as is involved in their identification and chemical classification.

Instructions in these general principles is accompanied by a course of lectures, the chief object of which is to supply the experimental demonstrations required.

Books of Reference.—First Principles of Chemical Philosophy, Cooke; Manual of Chemistry, Fowne; Einleitung in die Moderne Chemie, Hofmann; Histoire des Doctrines Chimiques, A. Wurtz; Dictionary of Chemistry, Watts; Manual of Mineralogy, Dana; Metals, Bloxam; Handbuch der Organischen Chemie, Beilstein.

Department of Analytical Chemistry.

In this department the course of instruction is arranged with special reference to the wants of the mechanical engineer.

Qualitative analysis is studied during the second year by the usual laboratory practice, and each student must give satisfactory evidence of his ability to make a thorough qualitative analysis of the more commonly occurring technical products before advancement to quantitative analysis.

The analyses performed during the third year consist principally of iron ores, limestones, fuels, furnace gases, alloys, paints, waters, cast iron and steel, slags and lubricating oils.

Schemes for analysis are written out for each case, after a thorough qualitative examination has first been made by the student, and this method is pursued in preference to using the usual quantitative text-books.

Rapidity of execution with accuracy is insisted upon, the correct determination of

the few principal constituents of the substance under examination being of the first importance, rather than the determination of all.

The latter is more the province of the analytical chemist than of the mechanical engineer.

A graduate of the Institute should be thoroughly familiar with the properties of the materials he expects to use in the practice of his profession; their origin and process of manufacture. He should have a definite idea of their chemical composition, and know what elements exert a good as well as an injurious influence upon the materials for the purposes they are to be used, and he should be able to determine the amounts of such elements whenever necessary.

Practical problems of varied character are constantly being brought to the Department of Analytical Chemistry by persons engaged in the various manufacturing industries, and the results, when of sufficient interest and of a general character, are given to the students.

Visits are made from time to time by the Professor of Analytical Chemistry to various metallurgical and smelting works for the purpose of obtaining the latest methods in use at the works and in their analytical laboratories. By these means it is believed the student secures the benefits of all the new and useful processes in the shortest possible time.

Books of Reference.—Fenton's Qualitative Analysis; Fresenius' Qualitative Analysis; Fresenius' Quantitative Analysis; Fleischer's Volumetric Analysis; Wanklyn's Water Analysis; Allen's Commercial Organic Analysis; Troilius' Iron and Steel Analysis; Watts' Dictionary of Chemistry.

Department of Engineering.

The chief aim of this department is to instruct the student in those subjects which will enable him to design a machine, or a plant of machinery, in accordance with scientific principles; or to review such as have been previously made.

During the junior year the studies will pertain to the mechanical properties of building materials, foundations of structures, the mechanism of engines, and the general principles of designing machinery. Problems are frequently given under each of these heads to make certain that the student can apply the principles which he has studied to practical cases.

During the senior year the principles of energy will be studied in connection with such motors as hydraulic motors, windmills, steam, air and gas engines, pumps, compressors, refrigerators and special machines of known types. As much time as circumstances will permit will be given to Thermodynamics and its applications. Problems requiring designs, and others requiring numerical solutions, are occasionally given. Instruction is given chiefly through text-books and frequent lectures.

The plan of the instruction consists in requiring labor on the part of the student, ascertaining by suitable tests if knowledge is acquired, and giving assistance when needed.

At the close of the course, a "Graduating Thesis" is required of every student, in which he is expected to exhibit his proficiency by designing and describing the construction and management of some machine, by planning some manufacturing establishment, giving bills of materials and estimates of cost, or by describing some original research, in the course of which he has investigated some subject of importance to the profession and obtained new and valuable information and data capable of practical application in mechanical engineering. These are deposited in the Institute, and are open for inspection.

Instruction in regard to the proper materials for tools, their forms and modes of use in the construction of machines, is given in "Shop-work."

Experiments to test certain theoretical principles are given in the "Course of Experimental Mechanics."

Books of Reference.—Mechanics of Engineering, Moseley; Mechanics of Engineering, Weisbach; Strength of Machinery, Van Buren; Proportions of Steam Engines, Marks; Friction and Lubrication, Thurston; Workshop Appliances, Shelley; Steam Boilers, Wilson; Steam Engine, Goodeve; Materials of Construction, Thurston; Lowell

Hydraulic Experiments, Francis; Theory of Heat, Maxwell; The Steam Engine, Holmes; Manual of Marine Engineering, Seaton; Manual for Railroad Engineers, Vose; Manual for Mechanical Engineers, Clark; Machine Design, Unwin; Carpentry, Tredgold; Casting and Founding, Spretson; Specifications and Contracts, Haupt; Aid-book, Mattheson; Mechanical Theory of Heat, Clausius; Elementary Treatise on Heat, Stewart; The Windmill, Wolff; Treatise on Heat, Box.

Department of Experimental Mechanics and Shop-work.

The work-shop fitted up by President Morton, and formally presented by him to the Trustees on the 14th of May, 1881, is provided with machine and other tools, so as to accommodate fifty students at one time.

The "work-shop" course of the Institute is intended to supply the student with a knowledge, as complete as possible, of the best existing appliances, methods and processes necessary to the construction of such mechanical designs as the theoretical part of the Institute's course will enable him to originate.

In accordance with this plan, the Institute is provided with a machine and carpenter shop, an iron and brass foundry, and a blacksmith's shop, in which the student is first sufficiently familiarized with the working of wood and metal, to enable him to recognize and appreciate differences in machines, tools and methods of manipulation in founding and blacksmithing, after which he is taken to certain large manufacturing establishments, so selected as to enable him to see and examine, on a large scale, that with which the Institute's shops have afforded him familiarity in an elementary and limited degree.

The shop schedule provides:

1. That classes work consecutive days each week in the shop so that any work started in a machine or at any spot on the first day of attendance is not disturbed until the end of the weekly working interval.

2. That no work is assigned to any class on Saturday, thus making that day available for *extra work*, so that students joining the Institute's advanced classes can be given an opportunity to use the shop tools, etc., during other hours than those assigned to their class. They may therefore gradually make up such deficiency in shop practice as may exist compared with the students who have entered as freshmen. Saturday as a day for *extra work* also provides a time for the "working off" of conditions in shop work—an important detail quite impossible of attainment heretofore, inasmuch as Saturday had to be devoted by the shop to the regular instruction of the juniors, and Friday, the only idle day for the shop, found conditioned students engaged in other departments under the regular roster.

3. That all pattern-making exercises are undertaken after instruction in moulding is finished, and fall upon dates during the Supplementary Term, where continuous intervals of time are available for the work and when the wood-turning lathes are nearly all without claimants—two conditions quite essential to the attainment of any definite results in a subject so exacting as pattern-making.

4. That the shop exercises are completed before the close of the junior year, thus enabling experimental work, such as the slide-valve exercises, tests of strength of materials, etc., as per list in schedule, to be undertaken contemporaneously with the study of these matters in engineering and mechanics, and also relieving the experimental programme for the supplementary term at the end of the junior year of its items of minor importance, which will enable more attention to be given to the important matters, such as engine testing, etc.

Students work in pairs on the metal lathes, planers, drill press, miller, at steam-fitting and blacksmithing, and in groups of four at millwrighting, this arrangement having been found to give much better results than working singly.

Part of the work that previous to this time has been done in the senior supplementary term has been incorporated in the shop-work course, viz.: Tension of belting in transmitting different horse-power; rate of flow of water under a constant head through

different lengths of pipe, and through pipes containing globe valves, cocks and elbows; use of steam engine indicator in connection with a slide-valve engine and model specially arranged to secure to the student a thorough knowledge of the exact signification of the several portions of an indicator card.

Determination of the maximum load that can be sustained by tension pieces of tool steel, machine steel, wrought iron, cast iron, and brass that have been turned to a standard size during the metal lathe course.

Elasticity of a pine beam 32 feet long, supported at its ends and loaded at various points along its length.

All this experimental work occurs after the first regular term of the sophomore year, at which time the students will have acquired sufficient knowledge to calculate the results from formulæ, as well as to derive them from experiment. In the moulding course the cupola is used as often as a sufficient number of molds are prepared to consume an entire charge of metal. With six students in the foundry, casting occurs every second day.

The time devoted to shop-work by each student is distributed as follows :—

Metal lathe	225	hours.	Carpentry	25	hours.
Pattern-making	100	"	Brass-turning	20	"
Metal planer	65	"	Steam-fitting	16	"
Vise work	40	"	Steam boilers	16	"
Molding	40	"	Metal testing	8	"
Wood-turning	40	"	Elasticity of pine beam	8	"
Blacksmithing	40	"	Flow of water through pipes	8	"
Miller	32	"	Friction of belting	8	"
Drill press	24	"	Indicator cards	8	"
Millwrighting	24	"			

Course of Experimental Mechanics.

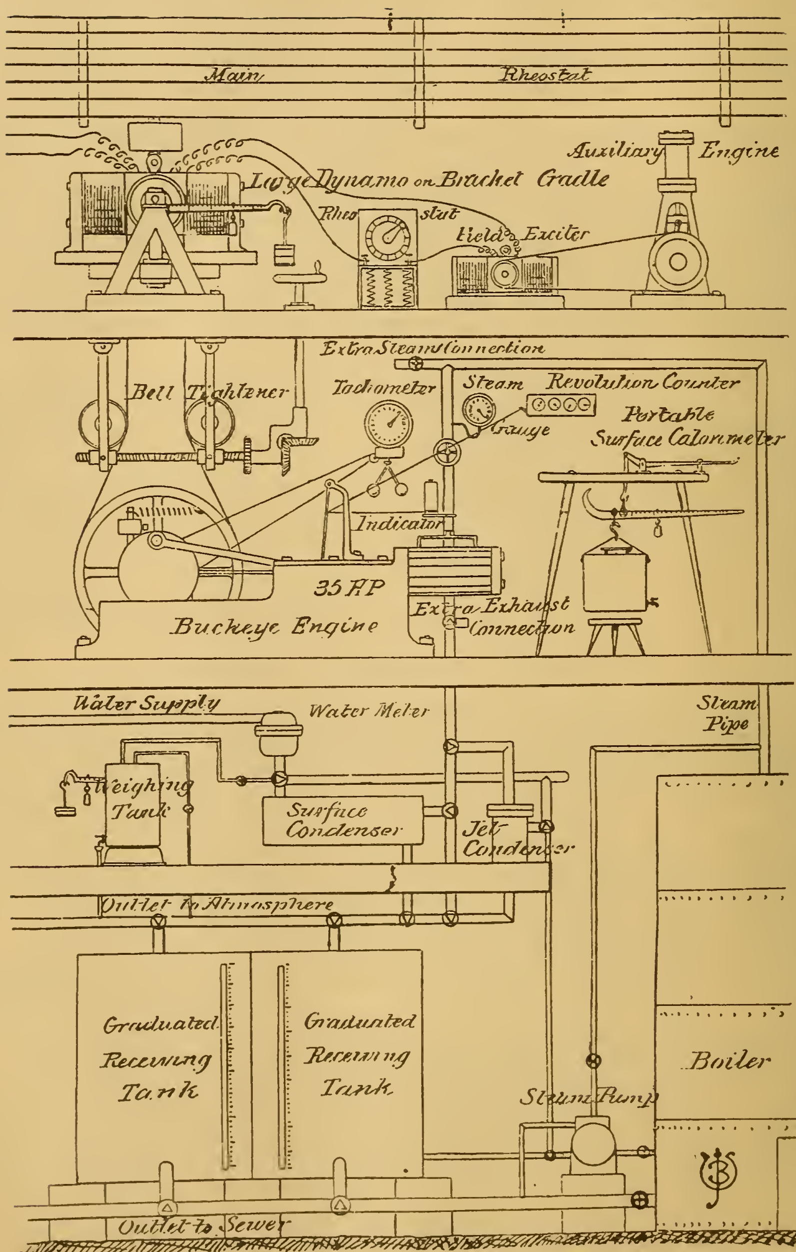
This is a course given to the senior class during the supplementary term, and during a portion of the regular terms, which is intended to be supplementary to the work of the third year in Analytic and Applied Mechanics, Resistance of Materials and Heat, as well as preparatory to the study of the steam engine, pursued during the regular terms of the fourth year.

The interest manifested in these exercises during the four years in which they have been introduced has stimulated the department to make systematic arrangements for their continuance and for more thorough instruction in the execution of the experimental tasks. It is arranged under eight groups, and each group is capable of affording three tasks, each of which, students working in pairs, can perform in one day of eight hours. Consequently, provision is made for forty-eight students as a maximum. The programme of operations is as follows :—

During the months of July and August a party of assistants will rehearse the exercises, so that no time need be lost in preparations during September. The same assistants will take charge of a group of exercises during the Supplementary Term, and will aid students to secure, without loss of time, the data belonging to experiments. As soon as the data of any one experiment are secured, the students will report to the Chief Instructor, who will direct such calculations as are necessary to deduce from the observed data the desired conclusions, after which the next exercise in regular order will be assigned. Blanks for the data to be observed and for the results to be deduced will be in readiness, so that the success of each task within the specified time may be assured.

Department of Engineering Practice.

During the month of November a course of lectures on the Practice of Engineering is delivered, after the plan adopted in medical schools and known as clinical instruction. The lecturer in this instance being one whose range of practical experience extends over


Main
Rheostat
Large Dynamo on Bracket Cradle
Auxiliary Engine
Rheostat
Field Exciter
Extra Steam Connection
Belt Tightener
Tachometer
Steam Gauge
Revolution Counter
Portable Surface Calorimeter
Indicator
35 HP
Buckeye Engine
Extra Exhaust Connection
Water Supply
Water Meter
Steam Pipe
Weighing Tank
Surface Condenser
Jet Condenser
Outlet to Atmosphere
Graduated Receiving Tank
Graduated Receiving Tank
Boiler
Steam Pump
Outlet to Sewer

a period of more than forty years: in the rolling mill, in locomotive building and in general millwright practice, machine tool building, hydraulic power as applied to hoisting, etc. The object being to teach shop practice, the management of workmen, cost of production and shop superintendence generally.

Facilities for Engine Testing in the Department of Experimental Mechanics.

The accompanying schematic plan exhibits the general arrangement of apparatus which has been gradually accumulated during the past three years for experimental practice in engine testing, and which is now utilized in a systematic manner during the summer term for instruction in experimental mechanics provided for the Senior Class after the completion of their Junior year.

By reference to the drawing, it may be seen that the arrangements comprise a 35 horse-power Buckeye engine, placed upon an intermediate level, so that the power developed from it may be absorbed by a dynamo on an upper level, and the steam consumed may be received into condensers or graduated tanks upon lower levels.

The arrangements upon the highest level for absorbing and measuring the power developed by the engine consist of a large dynamo, mounted upon a Brackett cradle dynamometer, whose electric energy may be received by the large main rheostat, whence it is radiated into the atmosphere at a uniform rate.

This dynamo is excited by an auxiliary machine driven by a separate small engine, so that, by means of the field rheostat, the resistance of the large dynamo as a load upon the engine may be made equivalent to any horse-power from 3 to 35, and such load be maintained so constant that the main engine can be given a fixed cut-off and run at a fixed speed without the use of the governor. Any given load can thus be maintained for an unlimited period of time. The engine can be entirely relieved of all load except its own friction by means of the belt-tightener shown.

The Brackett dynamometer is capable of measuring twentieths of a horse power with precision.

The condensing facilities comprise both a jet and a surface condenser. The latter form is the most recent acquisition to the plant, and has been made through the generosity of the inventor of the condenser, Mr. F. M. Wheeler.

In using the jet condenser, the mixture of condensed steam and condensing water is delivered by the air pump into one of the graduated tanks, whose capacity is about 8,000 pounds, and there measured. The condensing water is measured by the water metre at the entrance to the condenser, and the steam used by the engine is, therefore, determinable by difference from the quantity received in the tank.

In using the surface condenser, the condensed steam is weighed directly by the platform scales shown, and the condensing water again determined by the metre.

The water fed to the boilers is determined by drawing it from one of the graduated tanks, by which means a check is available upon the steam consumption, as determined by the condensers, etc., at the opposite end of the system.

A recording steam gauge, a revolution counter, a centrifugal speed indicator, or tachometer, indicators, clariometer, etc., are included, as indicated on the drawing.

Extra connections for steam and exhaust render the facilities described available for testing the economy of portable engines, which the department is occasionally called upon to examine.

Opportunity is provided for an inspection tour, to be made by the Senior Class. The following is the usual route pursued:—

April 1—Bethlehem, Eagle Hotel—Steel and zinc manufacture—Bethlehem Iron and Zinc Works.

April 2—Philadelphia, Girard House—(1) Welding, fitting and testing of wrought iron pipe—Morris & Tasker's Pascal Iron Works. (2) Arrangement and outfit of first-class machine shops—Sellers' Machine Works. (3) Locomotive manufacture—Baldwin Locomotive Works. (4) Marine engines and ship-building—Cramp's Ship Yard.

April 5—Hartford, Allyn House—(1) Machine tools, taps and dies, and standard

gauges; gear cutting by machinery and drop forging—Pratt & Whitney Co. (2) Improvements in automatic screw machinery; recovery of oil from metal cuttings; straightening of bar iron—Hartford Screw Co. (3) Machinery for manufacture of repeating rifles; manipulation of Gatling gun; construction of disc and Baxter engines; automatic wood-screw machinery; latest attempt at setting type by machinery—Colt's Armory. (4) Latest methods of heating and ventilation—Hartford State House. (5) Extreme case of use of fast speed engines for large steam power plant—Willimantic Linen Mill.

April 6—Springfield, Massasoit House—(1) Construction and use of turbine water wheels—Holyoke Machine Works. (2) Testing of turbines—Holyoke Testing Flume. (3) Manufacture of paper—Dickinson Paper Mills.

April 7—Boston, United States Hotel—(1) Most improved machinery for rapid working of brass—Hancock Inspirator Co.'s Shops. (2) Testing of large sizes of materials—Emery Testing Machine, Watertown Arsenal. (3) Types of modern pumping engines: Leavitt walking-beam and fly-wheel type, and Worthington direct acting type—Boston Sewage Pumping Station, Dorchester.

April 8—Providence, Narragansett House—(1) Manufacture of machines in duplicate by most improved machine processes—Wilcox & Gibbs' Sewing Machine; machine moulding, pickling and annealing of cast-iron for milling machine work—Brown & Sharp Manufacturing Co. (2) Supply water to cities and towns; direct distribution—Hope Street Station, Corliss five (5) cylinder direct engine and Nagle-geared form of engine; reservoir distribution—Pawtucket Waterworks, Corliss compound engines and Swan turbine water wheels.

April 9—Fall River, Wilbur Hotel—(1) Manufacture of cotton fabrics and standard single Corliss engine—Barnard Mills. (2) Medium high-speed engines and latest types of compound mill engines—Globe Mills.

Department of Applied Electricity.

In this department, which has now been in successful operation for three years, the theoretical knowledge acquired in our previous regular course has been supplemented by systematic laboratory instructions; in the management and care of batteries, galvanometers, rheostats, electrometers, condensers, etc.; in the measurement of resistances of wires, batteries, insulation, resistance, and capacity of cables, electro-motive force, etc. These and other experiments have been made sufficiently numerous and varied to familiarize the student with electrical terms, as potential, electromotive force, resistance, etc.; to give him a realizing sense of the various electrical magnitudes, as Volts, Ohm, Ampere, etc., and to point out the quantitative relations of these units to the ordinary mechanical ones.

Special attention is given to problems in connection with dynamo machines, such as the measurement of powerful currents, determinations of efficiency in generators and in electric motors, photometry of arc and incandescent lamps, consumption of energy in generators, conductors and lamps, dimensions of wires for various currents, etc.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY (BOSTON).

Historical Sketch.—The foundation of the Massachusetts Institute of Technology was laid in a report by Professor William B. Rogers, entitled "Objects and Plan of an Institute of Technology, including a Society of Arts, a Museum of Arts, and a School of Industrial Science." A charter for the institution thus projected was granted by the Legislature of Massachusetts in an Act dated April 10, 1861. In this charter, the threefold plan outlined by Professor Rogers, who became the first President of the Institute of Technology, was preserved.

Of the three integral parts of the Institute, the Society of Arts was first organized, and has continued ever since to hold semi-monthly meetings from October to May of each year.

The School of Industrial Science was opened in February, 1865, in temporary rooms in Mercantile Building, Summer Street, Boston, with twenty-seven pupils, of whom fourteen graduated with the diploma of the Institute of Technology in 1868. The first building of the Institute of Technology, now known as the Rogers' Building, was erected on land conceded by the State, and was occupied by the chemical department in the spring of 1866. In the fall of the same year the whole School of Industrial Science, together with the Society of Arts, was removed to the same structure.

Two subsidiary schools have been organized under the control of the Corporation of the Institute; one, the Lowell School of Practical Design; the other, the School of Mechanic Arts.

Less formal action has been taken for carrying out the purposes of the founders of the Institute of Technology in the establishment of a Museum of Arts. Varied and valuable collections have been made, which, taken together, would constitute no inconsiderable foundation for such a museum; but, thus far, this material has been divided, so that the portions especially relating to individual departments of study and research might be placed within easy reach of the students and teachers respectively concerned therewith.

Buildings.—The buildings now occupied are (1) the Rogers Building, on Boylston Street, devoted to the engineering departments and to instruction in mathematics, mechanics, literature, history, political science, geology, mineralogy, and physiology; (2) the New Building, corner of Boylston and Clarendon Streets, mainly devoted to the departments of chemistry, physics, civil engineering, and architecture, and to instruction in language; (3) a series of laboratories, drawing and recitation rooms, at the foot of Garrison Street, mainly devoted to work in the mechanic arts and to the instruction of the Mechanic Arts School and the Lowell School of Design; (4) a gymnasium and drill hall, on Exeter Street.

SCHOOL OF INDUSTRIAL SCIENCE.

The Faculty of this School is particularly strong, consisting of twenty-seven professors or assistants, and forty-eight instructors in technological subjects, as follows:—

Francis A. Walker, Ph.D., LL.D., President.
John D. Runkle, Ph.D., LL.D., Walker Professor of Mathematics.
William A. Atkinson, A.M., Professor of English and History.
George A. Osborne, S.B., Professor of Mathematics.
Robert H. Richards, S.B., Professor of Mining Engineering and Metallurgy.
Charles P. Otis, A.M., Ph.D., Professor of Modern Languages.

Alpheus Hyatt, S.B., Custodian of the Boston Society of Natural History, Professor of Zoölogy and Palæontology.

William H. Niles, Ph.B., A.M., Professor of Geology and Geography.

Charles R. Cross, S.B., Thayer Professor of Physics, and Director of the Rogers' Laboratory.

Gaetano Lanza, S.B., C.E., Professor of Theoretical and Applied Mechanics; in charge of the Department of Mechanical Engineering.

Theodore M. Clark, A.B., Professor of Architecture.

Thomas M. Drown, M.D., Richard Perkins Professor of Analytical Chemistry.

George F. Swain, S.B., Professor of Civil Engineering.

Eugene Letang, Assistant Professor of Architecture.

Jules Luquiens, Ph.D., Associate Professor of Modern Languages.

William T. Sedgwick, Ph.D., Associate Professor of Biology.

Silas W. Holman, S.B., Associate Professor of Physics.

Webster Wells, S.B., Associate Professor of Mathematics.

Lewis M. Norton, Ph.D., Associate Professor of Organic and Industrial Chemistry.

William O. Crosby, S.B., Assistant Professor of Mineralogy and Lithology.

Alfred E. Burton, S.B., Assistant Professor of Topographical Engineering.

Peter Schwamb, S.B., Assistant Professor of Mechanism and Director of the Workshops.

Cecil H. Peabody, S.B., Assistant Professor of Steam Engineering.

Thomas E. Pope, A.M., Assistant Professor of Analytical Chemistry.

Linus Faunce, S.B., Assistant Professor of Drawing.

Dwight Porter, Ph.B., Assistant Professor of Civil Engineering.

Frederick W. Clark, S.B., Assistant Professor of Mining and Metallurgy.

C. Frank Allen, S.B., Assistant Professor of Railroad Engineering.

Henry K. Burrison, S.B., Instructor in Mechanical Drawing.

Ellen H. Richards, A.M., S.B., Instructor in Sanitary Chemistry.

Arthur N. Wheelock, A.M., Instructor in English.

Samuel G. Stephens, Instructor in Mechanical Engineering.

S. Homer Woodbridge, A.M., Instructor in Physics and Lecturer on Ventilation.

Gen. Hobart Moore, Instructor in Military Tactics.

William W. Jacques, Ph.D., Instructor in Telegraph Engineering.

Howard V. Frost, S.B., Instructor in General Chemistry.

Clement W. Andrews, A.M., Instructor in Organic Chemistry.

Charles L. Adams, Instructor in Freehand Drawing.

Jerome Sondericker, S.B., C.E., Instructor in Applied Mechanics.

Joseph J. Skinner, Ph.D., Instructor in Mathematics.

Davis R. Dewey, Ph.D., Instructor in History and Political Science.

Charles A. French, S.B., Instructor in Mathematics.

George H. Barton, S.B., Instructor in Determinative Mineralogy.

George R. Underwood, S.B., Instructor in Industrial Chemistry.

Frederic L. Bardwell, S.B., Instructor in General Chemistry.

Arthur J. Purinton, S.B., Instructor in Mechanical Engineering.

Harry W. Tyler, S.B., Instructor in Mathematics.

George T. Dippold, Ph.D., Instructor in Modern Languages.

William L. Puffer, S.B., Instructor in Physics.

Allyne L. Merrill, S.B., Instructor in Mechanical Engineering.

Henry B. Talbot, S.B., Instructor in Chemical Analysis.

Eleazer B, Homer, S.B., Instructor in Architecture.

Dwight H. Perkins, Instructor in Architecture.

Eugene H. Babbett, A.B., Instructor in Modern Languages.

John F. Machado, Instructor in Spanish.

Charles W. Eaton, Instructor in Drawing.

Edward G. Gardiner, Ph.D., Instructor in Biology.

Peter Burns, Instructor in General Chemistry.

Frederick Fox, S.M., Assistant in Sanitary Chemistry.

Dana P. Bartlett, S.B., Assistant in Mathematics.
Harry E. H. Clifford, S.B., Assistant in Physics.
Edward S. Foss, S.B., Assistant in General Chemistry.
Edward F. Miller, S.B., Assistant in Mechanical Engineering.
Arthur G. Robbins, S.B., Assistant in Civil Engineering.
Arthur A. Noyes, S.M., Assistant in General Chemistry.
Ralph E. Curtis, S.B., Assistant in Mechanical Engineering.
Fred P. Emery, A.B., Assistant in English and History.
John M. Fox, S.B., Assistant in Drawing.
William O. Hildreth, S.B., Assistant in Mechanical Engineering.
Charles B. Kendall, S.B., Assistant in General Chemistry.
Walter S. Moody, Assistant in Physics.
George W. Patterson, jr., A.B., S.B., Assistant in Mathematics.
Timothy W. Sprague, S.B., Assistant in Mining and Metallurgy.
Alfred J. Wakeman, S.B., Assistant in Chemical Analysis.
Joseph P. Grabfield, Ph.D., Assistant in General Chemistry.
William E. Roberts, Assistant in Drawing.

The Instructors and Assistants in the Mechanic Arts are :

Theodore B. Merrick, Instructor in Wood-work and Foundry-work.
James R. Lambirth, Instructor in Forging.
Robert H. Smith, Instructor in Machine-Tool Work.
John W. Raymond, jr., Assistant in Forging.
Frank W. Leavitt, Assistant in Wood-work.
William S. Carpenter, Assistant in Machine-Tool work.

Lecturers for the Current Year.

George W. Blodgett, S.B., on Applications of Electricity to Railway Working.
Henry M. Howe, A.M., S.B., on Metallurgy.
C. Howard Walker, on History of Ornament.
Ross Turner, on Water Color and Sketching.
Charles W. Hinman, S.B., on the Manufacture of Illuminating Gas.
Walter S. Allen, S.B., on the Manufacture of Fertilizers.
Eliot Holbrook, S.B., on Railroad Maintenance.
Charles E. Mills, in charge of Life Class.
David A. Gregg, on Fine Art.
David L. Barnes, on Locomotive Construction.
Anthony C. White, S.B., on the Distribution of Electricity for Commercial Purposes.
Edward Blake, Ph.B., on the Construction and Applications of Electromotors.

Requirements for Admission.

To the Regular Courses.

First Year—To be admitted as a regular student in the first-year class, the applicant must have attained the age of seventeen years, and must pass a satisfactory examination in Arithmetic, Algebra, Plane Geometry, French, English, Grammar and Composition, History and Literature, and Geography.

The requirements in the various subjects are as follows:

1. *Arithmetic.*—Prime and composite numbers; greatest common divisor and least common multiple; ratio and proportion; common and decimal fractions; percentage; simple and compound interest; compound numbers; metric system of weights and measures; square root. A satisfactory treatment of these subjects may be found in either Seaver and Walton's, Wentworth and Hill's, or Greenleaf's Complete Arithmetic.

2. *Algebra.*—Fundamental operations; use of parentheses; factoring; highest common factor; lowest common multiple; fractions, simple and complex; simple equations, with one or more unknown quantities; involution of monomials and polynomials; evolution of monomials and polynomials and the cube root of numbers; the theory of exponents with applications; radicals, including rationalization, imaginary quantities, properties of quadratic surds, square root of a binomial surd, and solution of equations containing radicals; quadratic equations; equations in the quadratic form; simultaneous quadratic equations; theory of quadratic equations; ratio and proportion; arithmetical progression; geometrical progression; binomial theorem, with proof for a positive integral exponent. A satisfactory treatment of the topics in Algebra may be found in either of the following text-books: Wells' Academic, Wentworth's Elementary, or Todhunter's Algebra for Beginners.

3. *Plane Geometry.*—As much as is contained in the first five books of Wells', Chauvenet's, or Wentworth's Geometry. Much more importance will be attached to the applicant's ability to demonstrate new propositions than to reproduce the demonstrations of those propositions which he has learned in his text-book.

NOTE—*Solid Geometry.*—Candidates will be allowed an examination, in September, in Solid Geometry, and if successful, will be excused from studying the subject after admission.

4. *French*—Elements of grammar, and some practice in translation. At least a year of careful work upon Part I. of Otto's Grammar, and fifty or sixty pages of easy reading, represents, in general, the required amount. Practical exercises, both oral and written, are essential.

NOTE—*German.*—Candidates not prepared in French may substitute an equivalent in German. Otis' "Elementary German" represents the required amount. In this case the German will be continued and finished during the first year, and the following two years will be devoted to French.

5. *English.*—The applicant will be expected to be reasonably well acquainted with the essentials of English grammar, and to be able to detect common errors in style; but it is recommended to teachers that in preparing candidates their chief attention be given to simple practical exercises in English composition.

6. *History and Literature.*—The candidate will be expected to give evidence of a *real* acquaintance with some portion of History. The examination paper will presume acquaintance with the main facts of the history of the nineteenth century. But any candidate who may so elect will be given, as a substitute therefor, a paper which presumes acquaintance with (1) the history of England since the Great Rebellion; or (2) the history of the North American Colonies and the United States; or (3) the history of Greece and Rome. This choice is offered in order that the requirements of the Institute may not unduly disturb the courses of study in the various preparatory schools.

In Literature the applicant must give evidence that he has really read and is familiar with some of the classical English writers in prose and verse, and that he has at least a general knowledge of the place in English history of England's greatest writers.

Experience having shown that the specifying of books or of particular courses of study, in subjects where the methods of teaching vary so widely, proves a great inconvenience to many teachers in the arrangement of their classes, the above requirements have designedly been made as general as possible, in the hope that this course may lead to a more genuine style of preparation in English subjects, and to the avoidance of all "cramming" of text-books.

7. *Geography.*—The text-books intended for use in grammar schools usually represent the amount of preparation required. Practice in freehand map-drawing from memory is strongly recommended.

In general, the training given in the best high schools and academies will afford suitable preparation. To the student, the importance of thorough preparation is great; since the character and amount of instruction given in the school from the outset leave little opportunity for one imperfectly fitted to make up deficiencies, and render it impossible for him to derive the full benefit from his course, or perhaps even to maintain his standing.

Students will find their progress in Physics and Chemistry promoted by making themselves thoroughly familiar with so much of Physics as is contained in Balfour Stewart's Primer.

A knowledge of the Latin language is not required for admission; but the study of Latin is strongly recommended to persons who purpose to enter this school, as it gives a better understanding of the various terms used in science, and greatly facilitates the acquisition of the modern languages. Those who intend to take the course in Natural History will find it advantageous to acquire also the elements of Greek.

Second, Third and Fourth Years.—To be admitted as a regular student in either of these classes, the applicant for this advanced standing must have attained the proper age (eighteen, nineteen, and twenty years respectively), must in general pass satisfactorily the examination for admission to the first-year class, and examinations on all of the subjects given in the earlier years of the course which he desires to enter.

Graduates of colleges are admitted to the Institute without examination, and will be permitted to enter any of the courses at such a point as their previous range of studies shall allow. If prepared to enter upon most of the studies of the third year they will be afforded opportunity to make any studies of the earlier years in which they are deficient: they will, in general, be credited with all subjects in earlier or later years in which they can show, by examination or otherwise, a standing satisfactory to the Faculty, and be received provisionally as regular students.

Courses of Instruction.

The School of Industrial Science of the Massachusetts Institute of Technology provides an extended series of scientific and literary studies, and of practical exercises. The courses of study include the Physical, Chemical, and Natural Sciences and their applications; Pure and Applied Mathematics; Drawing; the English, French, German, and other Modern Languages; History; Political Science; and International and Business Law. These studies and exercises are so arranged as to afford a liberal and practical education in preparation for active pursuits, as well as a thorough training for most of the scientific professions.

The following regular courses of study, each of four years duration, have been established; and, for proficiency in any one of them, the degree of Bachelor of Science, S.B., in the course pursued is conferred. Descriptions of the courses are given.

I. Civil and Topographical Engineering.
II. Mechanical Engineering.
III. Mining Engineering.
IV. Architecture.
V. Chemistry.
VI. Electrical Engineering.
VII. Natural History.
VIII. Physics.
IX. General Course.

Options.—To enable a student to devote himself more closely to some one or more chosen branches of the professional or scientific course which he has undertaken, optional lines of study are introduced into the later years. In some cases the selection of later options is positively determined by the earlier ones, owing to the requirement of certain subjects as preparation for others; in others, a wide choice is offered throughout all the years, the difference in this respect arising largely from the nature of the topics involved.

Five Years' Course.—Students purposing to take the degree of the Institute, but for exceptional reasons (as ill-health or inadequate preparation) finding it advantageous to take fewer studies at any one time than are prescribed in the schedules for the regular four years' courses, may pursue a course arranged with a view to a fifth year, without becoming classified as special students. The five years' course includes in any department all the studies of the regular course, in general in the same sequence. This is all

that is required, yet, owing to the additional time taken, an opportunity for more extended study of professional or other topics will be possible. Students in this course are under the especial direction of a committee appointed by the Faculty.

Advanced Courses of study may be pursued either with or without reference to the advanced degrees authorized by the corporation.

Free Evening Courses of scientific and literary instruction, open to both sexes, are given each year, being supported by the trustee of the Lowell Institute.

Schedules and Descriptions of the Courses.—The following pages contain schedules showing the distribution of studies throughout each of the several courses given in the School of Industrial Science. Each schedule is preceded by a brief description of the course.

The first year for all courses is the same, and contains subjects which are considered essential as preliminary training, and as a foundation for the more strictly professional studies of the later years of all courses. At the end of the first year, the regular student selects the course which he will pursue during the remaining three years; and his work becomes more specialized thereafter as it progresses.

The Schedule of Topics gives information as to the nature, number, and period of occurrence of exercises in any particular topic, the name of the instructor, and the preparation required for admission to exercises in that subject. This is particularly of service to the regular student in selecting options, and to the special student in affording the means of ascertaining precisely what instruction is given in any topic which he may desire to pursue, when, at what length, and by whom it is treated, and exactly what preparation will be demanded of every applicant for the topic considered. By careful consultation of this schedule, the special course may be so planned that the earlier studies shall afford suitable preparation for the more advanced work towards which the course is directed.

REGULAR COURSES.

Schedules of Prescribed and Optional Studies.

First Year.

Common to all Regular Courses.

First Term.	Second Term.
Solid Geometry.	Algebra.
Algebra.	Plane Trigonometry.
General Chemistry.	General Chemistry.
Chemical Laboratory.	Chemical Laboratory.
History of the English Language.	Political History since 1815.
English Composition.	French (or German).
French (or German).	Mechanical and Freehand Drawing.
Mechanical and Freehand Drawing.	Military Drill.
Military Drill.	

I.—Civil Engineering.

This course is designed to give the student a thorough training, both theoretical and practical, in the sciences and principles upon which the sound practice of civil engineering is based. The principles taught are exemplified in the solution of many practical examples, and the student is made familiar with the instruments and the problems of general occurrence. The fourth year is devoted to purely professional work.

The rapid specialization now going on in the various departments of civil engineering renders it desirable that students should be allowed some choice of direction in their more advanced studies. The course therefore offers, principally in the fourth year, a selection among three options or lines of study—namely, a General Course in Civil Engineering; a course in which more than usual attention is devoted to roads, railroads, and railroad management; and a course giving special attention to geodesy, geology, and topography.

The more purely professional work is divided as follows: In the second year a full course in surveying, with extended practice in the field, supplemented by work in the drawing-room, prepares the student for the more advanced work to follow; the subjects of topographical drawing and mineralogy are also completed. In the third year the subject of railroads is taken up, with structure drawing, plane-table work, and mechanics. In the fourth year, equipped with his knowledge of mechanics, the student takes up the subjects of hydraulics, bridges, strength of materials, sanitary engineering, etc., as well as the advanced courses in railroads and in geodesy.

In the summer vacation following the third year, students taking the geodetic option are required to devote several weeks to field work in geology, topography, and geodesy.

First Year.

Same for all Courses.

Second Year.

First Term.

Surveying; Compass and Transit.
Plotting from Notes.
Analytic Geometry.
Physics.
Political Economy,
German.
Spherical Trigometry.

Options.

1, 2. Adv. Geometrical Drawing.
3 { Topographical Drawing.
Descriptive Astronomy.

Second Term.

Levelling; Profiles and Contours.
Differential Calculus.
Physics.
Physical Geography.
English Prose.
German.

Options.

1, 2 { Topographical Drawing.
3. Mineralogy.

Third Year.

First Term.

Railroad Engineering.
Field Work and Drawing in Railroad Location.
Structure Drawing.
Integral Calculus.
General Statics.
Physics: Lectures and Laboratory.
Structural Geology.
Literature.
German.

Options.

1, 2 { Foundations.
3. Chemical Geology.

Second Term.

Railroad Engineering.
Field Work and Drawing in Railroad Location.
Plane-Table Work.
Physical Laboratory.
Historical Geology.
European History.
German.

Options.

1, 2 { Kinematics and Dynamics.
Strength of Materials.
Stereotomy.
3 { Determinants.
Spherical and Prac. Astronomy.

Fourth Year.

First Term.

Principles of Construction.
Bridges and Roofs.
Hydraulic Engineering.
Strength of Materials.
Bridge Design.
Metallurgy of Iron.
Hydraulic Field Work.

Options.

1. Sanitary Engineering. R. R. Management, or Heating and Ventilation.
2. R. R. Eng. and Management.
3. Not definitely arranged; but to include Geodesy, Least Squares, Mining, and Special Geological Research.

Second Term.

Bridges aud Roofs.
Principles of Construction.
Thesis Work.

Options.

1. Hydraulic Engineering. Bridge or Hydraulic Design. Geodesy and Astronomy, or Machinery and Motors. Hygiene and Public Health, or Advanced Bridge Work.
2. Bridge Design. Railroads. Machinery and Motors.
3. Not definitely arranged; but to include Advanced Geodesy, Geology, and Topography, with Mining and other subjects.

II. Mechanical Engineering.

The course aims to equip the student with such training in pure and applied mathematics as shall qualify him to deal with the engineering problems of his profession from the most favorable standpoint. It attempts by instruction, both theoretical and practical, to acquaint him with engineering practice, and to give him a proper groundwork upon which to base a professional career. The more strictly professional work of the course may be classified as follows :—

1. Mathematics, physics, and applied mechanics, given outside the department; the last including the study of, and practice in testing the strength of materials.

2. Recitation-room work of the department proper, beginning with a study of the principles of mechanism, the construction of gear-teeth, etc., and continued by courses on machine tools and cotton machinery. Courses are given on the slide-valve and link, thermodynamics, theory of the steam-engine, and on steam-boilers. The fourth-year instruction includes such mechanical engineering subjects as dynamometers, governors, fly-wheels, springs, rotative effect of reciprocating parts, balancing of engines, injectors, steam-pumps, cylinder condensation, hydraulics and hydraulic motors, etc. An option is given among courses on marine engineering, locomotive construction, and mill engineering.

3. Drawing-room work. The students in the second year make working-drawings from measurements, and the drawings necessary in connection with the course in mechanism and gear construction. In the third year they make detail and assembly drawings from machinery, and this is followed by mechanism designs, and boiler drawings. In the fourth year a course in machine design is given.

4. Shop-work, including carpentry, pattern-making, forging, chipping, filing, aud machine-tool work.

5. Mechanical engineering laboratory work. This begins with drill in steam-engine tests in the second term of the third year, and is continued throughout the fourth year, including tests of boilers, pumps, power, etc., and a large amount of investigation.

First Year.

Same for all Courses.

Second Year.

First Term.

Principles of Mechanism.
Construction of Gear Teeth.
Drawing.
Carpentry and Wood Turning (shopwork).
Analytic Geometry.
Descriptive Geometry.
Physics.
Political Economy.
German.

Second Term.

Mechanism of Mill Machinery.
Mechanism of Shop Machinery.
Drawing.
Pattern Work (shopwork).
Differential Calculus.
Physics.
English Prose.
German.

Third Year.

First Term.

Slide Valve. Link Motion.
Thermodynamics.
Steam Engineering.
Drawing, Design, and Surveying.
Forging (shopwork).
Integral Calculus.
General Statics.
Physics : Lectures and Laboratory.
German.

Second Term.

Steam Engineering.
Drawing, Design, and Surveying.
Mech. Engineering Laboratory.
Forging, Chipping, and Filing (shopwork).
Kinematics and Dynamics.
Strength of Materials.
Physical Laboratory.
European History.
German.

Fourth Year.

First Term.

Mechanical Engineering.
Hydraulics.
Machine Design.
Mech. Engineering Laboratory.
Engine Lathe Work (shopwork).
Strength of Materials.
Metallurgy.
Heating and Ventilation.

Options.

1. Marine Engineering.
2. Locomotive Construction.
3. Mill Engineering.

Second Term.

Hydraulic Engineering.
Mech. Engineering Laboratory.
Engine Lathe Work (shopwork).
Strength and Stability of Structures.
Theory of Elasticity.
Constitutional History.
Thesis Work.

Options.

1. Marine Engineering.
2. Locomotive Construction.
3. Mill Engineering.

III. Mining Engineering.

This course is planned to prepare students for Mining, Geology, and Metallurgy, in accordance with the present demand for men. It is therefore laid out with three options. The first, for mine engineers, includes courses in calculus, applied mechanics, and motors. The second emphasizes the geological subjects, and leads towards the surveying of geological deposits, with special reference to their economical value. The third is devoted to the metallurgical and chemical sides of the profession.

The instruction in mining includes a course of lectures on the general character of the various deposits of useful minerals, and on the theory and practice of mining operations, such as prospecting, boring, sinking of shafts, driving of levels, different methods of working, hoisting, pumping, ventilation, etc, Ore-dressing and metallurgy are taken up in a course of lectures, accompanied by a series of continuous practical exercises in the mining and metallurgical laboratories in the concentration and smelting of ores.

A large amount of time is devoted in this course to chemistry, especially in its application to the analysis of inorganic compounds.

After the first term of the second year, the study of mathematics and applied mechanics is confined to those following the first option, students in the second option devoting themselves throughout the remainder of the course more particularly to physical, chemical, geological, and zoological work, while those in the third make a specialty of metallurgy and metallurgical chemistry.

During the second and third year, German, physics, mineralogy, and geology are prescribed; and courses in physical geography, biology, history, etc., are laid down in the several options.

First Year.

Same for all Courses.

Second Year.

First Term.

Chemical Analysis.
Physics.
German.
Analytic Geometry.
Surveying.
Drawing.
Blowpipe Analysis.

Second Term.

Chemical Analysis.
Physics.
German.
Mineralogy and Blowpipe Analysis.

Options.

1. Surveying; Diff. Calculus.
2. Physical Geography; Microscopy; Chemistry.
3. Surveying; Physical Geography; Chemistry.

Third Year.

First Term.

Chemical Analysis.
Geology.
German.
Mining.
Physics: Lectures.

Options.

1. Chemistry; Integral Calculus and Applied Mechanics.
2. Chemistry; Literature; Physical Laboratory; Zoology and Palæontology.
3. Literature; Special Methods; Physical Laboratory; Theoretical Chemistry.

Second Term.

Chemical Analysis.
Assaying.
German.
Mining.
Geology.
European History.

Options.

1. Applied Mechanics.
2. Chemistry; Physical Laboratory; Zoology and Palæontology.
3. Chemistry; Physical Laboratory.

Fourth Year.

First Term.	Second Term.
Chemical Analysis.	Chemical Analysis.
Mining Laboratory.	Modern History.
Modern History.	Metallurgy.
Ore Dressing.	Memoirs.
Metallurgy.	
Memoirs.	
Options.	*Options.*
1. Applied Mechanics.	1. Mining Laboratory ; Motors.
2. Special Geological Work.	2. Special Geological Work.
3. Special Metallurgical Work.	3. Mining Laboratory ; Motors.

IV. Architecture.

Throughout this, as in the engineering courses, extends a full course in mathematics, pure and applied, to serve as a basis for professional work.

The more strictly professional work begins in the second year, with the study of the five orders and their applications, and of architectural history. The student is made familiar with the materials and principles of construction, by lectures, problems and visits to buildings. The subject of specifications and contracts is thoroughly gone over. Practice in architectural design is continued throughout the course. Instruction is given in sketching in black and white and water-color, and drawing both from the cast and from life. Regular students pursue, in addition to this work, courses in German, French and English, and, through the second and third years, in physics.

All special students in Architecture are required to take in full, as a minimum, the following two years' course :—

Schedule of Partial Course in Architecture.

First Year.

First Term.	Second Term.
The Orders and Elements of Architecture.	Original Design.
Sketching and Water Color.	Sketching and Water Color.
Mechanical and Free-hand Drawing.	Mechanical and Free-hand Drawing.
Materials.	Shades, Shadows and Perspective.
Elementary Mechanics.	Common Constructions.
Architectural History.	Graphical Statics.
	Architectural History.

Second Year.

First Term.	Second Term.
Original Design.	Original Design.
Sketching and Water Color.	Sketching and Water Color.
Specifications.	Specifications and Contracts.
History of Ornament.	History of Ornament.
Problems in Construction.	Planning.
Ventilation and Heating.	Iron Construction.
Working-Drawings and Framing.	Schools, Theatres, Churches.
	Ventilation and Heating.
	Surveying.
	Stereotomy.
	Problems in Construction.

First Year.

Same for all Courses.

Second Year.

First Term.	Second Term.
Materials.	Original Design.
Architectural History.	Common Constructions.
Drawing.	Architectural History.
The Orders and Elements of Architecture.	Shades, Shadows and Perspective.
Analytic Geometry.	Sketching.
Physics.	Differential Calculus.
Descriptive Geometry.	Physics.
Political Economy.	English Prose.
German.	German.

Third Year.

First Term.	Second Term.
Original Design.	Original Design.
Sketching and Water Color.	Sketching and Water Color.
Working-Drawings and Framing.	Iron Construction.
Lectures on Fine Art.	Kinematics and Dynamics.
Integral Calculus.	Strength of Materials.
General Statics.	Stereotomy.
Structural Geology.	Physical Laboratory.
Physics : Lectures and Laboratory.	European History.
German.	German.
	Acoustics.

Fourth Year.

First Term.	Second Term.
Advanced Original Design.	Advanced Original Design.
History of Ornament.	Sketching in Water Color.
Sketching in Water Color.	Planning.
Problems in Construction.	Schools, Theatres and Churches.
Specifications.	Problems in Construction.
Strength of Materials.	Specifications and Contracts.
Lectures in Fine Art.	Constitutional History.
Heating and Ventilation.	Heating and Ventilation.
Advanced French.	Advanced French.
	Thesis Work.

V. Chemistry.

The course in Chemistry is primarily designed to prepare students for actual work in connection with manufactures based on chemical principles. It is also adapted to those who intend to become teachers of chemistry.

The class-room work consists of a full course of lectures on general chemistry, and lectures on theoretical, analytical, industrial and organic chemistry. The non-chemical studies, such as mathematics, physics, mineralogy, English, history, political economy and language, are selected with reference to their bearing on chemical work for their educational value.

The student spends a large part of the four years in the laboratories, the work being arranged as follows: In the first year there is general laboratory practice, in which the student is taught the nature of chemical processes and the use of chemical apparatus and is drilled in accurate habits of observation. Analytical chemistry—qualitative and quantitative—is begun in the second year, and continues throughout the course. Industrial, sanitary and organic laboratory practice follow in the third and fourth years.

While there is a certain prescribed course of study and work in the separate departments of chemistry, which all regular students must pursue, there is allowed great latitude of choice of subjects in the third and fourth years.

Effort is made to develop self-reliance in the student, so that he may be fitted to make his way without assistance. To this end he is obliged to make investigations, involving original research and reference to the appropriate literature in English, French and German.

First Year.

Same for all Courses.

Second Year.

First Term.

Chemical Analysis.
Theoretical Chemistry.
Physics.
German.
Political Economy.
Analytic Geometry.

Second Term.

Chemical Analysis.
Mineralogy and Blowpipe Analysis.
Physics.
German.
English Prose.

Options.

Differential Calculus.
Physical Geography.
Microscopy.

Third Year.

First Term.

Chemical Analysis.
Special Methods.
Industrial Chemistry.
Physics: Lectures and Laboratory.
German.
Literature.

Options.

Integral Calculus.
Geology.
General Physics (Electricity).
Sanitary Chemistry.

Second Term.

Chemical Analysis.
Theoretical Chemistry.
Industrial Chemistry.
Physical Laboratory.
German.
European History.

Options.

Physics.
Geology.
Sanitary Chemistry.
Industrial Chemistry.

Fourth Year.

First Term.	Second Term.
Chemical Analysis.	Organic Chemistry.
Abstracts.	Thesis Work.
Organic Chemistry.	
Physics.	
Metallurgy.	
Options,	
Physics.	
Language.	
Sanitary Chemistry.	
Laboratory Options.	
Analytical Laboratory.	
Organic Laboratory.	
Metallurgical Laboratory.	
Industrial Laboratory.	

VI. Electrical Engineering.

This course has been established in order to meet the wants of young men desirous of entering upon the practice of any of the various applications of electricity in the arts. Its leading studies are physics, especially theoretical and applied electricity, mathematics, and mechanical engineering.

A broad training is obtained by the introduction of full mathematical courses, and studies in history, literature, political economy, and French and German, the latter being of importance in obtaining at first hand a prompt acquaintance with invention and discovery. Of the technical studies of the course, those in mechanical engineering run parallel with the electrical subjects, since in many branches of electrical engineering a sound knowledge of mechanics, motors, of measurements of power and its transmission, etc., is essential. Thus, through the second year the students follow mathematics, mechanism, shopwork, and drawing, to about the same extent as those of the mechanical engineering course. In the third year the pure and applied mathematics, mechanics and mechanical engineering (lecture and laboratory work) are much the same in the two courses; and certain of these subjects are continued in the fourth year.

A full course in physics begins with the second year and continues, by lectures, recitations, and laboratory work, to the end of the third year. A portion of this is devoted to electricity; and at the middle of the second year, special readings and recitations on this topic are begun, by which the study of the theory of electricity is continued until the end of the third year. Work in the physical laboratory commences at the middle of the second year, and leads up to electrical measurements and testing. In the fourth year are given extended courses on the technical application of electricity to the telegraph, telephone, electric light, etc. Electrical study and research occupy the principal position in the fourth year. A series of advanced mathematical topics is also an important part of the work of this year.

First Year.

Same for all Courses.

Second Year.

First Term.	Second Term.
Physics: Lectures.	Physics: Lectures.
Mechanics and Acoustics.	Physical Laboratory.
Analytic Geometry.	Acoustics and Electricity.
Descriptive Geometry.	Differential Calculus.
Mechanism.	Mechanism.
Carpentry and Wood-turning.	Drawing.
Political Economy.	Metal Tuning.
German.	English Prose.
	German.

Third Year.

First Term.	Second Term.
Physics: Lectures and Laboratory.	Physical Lab.: Heat, Electricity
Electricity: Readings.	Electricity: Readings.
Integral Calculus.	Kinematics and Dynamics.
General Statics.	Strength of Materials.
Mechanical Engineering.	Mechanical Engineering.
Drawing.	Mech. Engineering Laboratory.
Literature.	Drawing.
German.	European History.
	German.

Fourth Year.

First Term.	Second Term.
Technical Applications of Electricity to Telegraph, Telephone, Electric Lighting, etc.: Lectures.	Technical Applications of Electricity.
Phys. Lab.: Electrical Testing and Construction of Instruments.	Advanced Physics, Memoirs, etc.
Testing of Telegraph Lines, Dynamo Machines, etc.	Physical Research.
Advanced Physics: Memoirs, etc.	Differential Equations.
Photometry.	Calculus of Variations.
Method of Least Squares.	Mech. Engineering Laboratory.
Mechanical Engineering.	Discussion of the Precision of Measurements.
Mech. Engineering Laboratory.	*Options.*
Applied Mechanics, Thermodynamics, Hydraulics, etc.	1. Quaternions.
	2. Physical Laboratory.
	3. Theory of Potential.

Note.—The student is advised to take Advanced German.

VII. Physics.

As distinguished from the professional or technical courses, *e.g.*, those in Engineering, Architecture, etc., there are offered by the Institute courses of a purely scientific nature, of which this is one. It contains a series of studies adapted to those who wish to become teachers of physics, or who desire to begin upon a course in pure science with a view to its further continuance, or wholly as a matter of training. A strong line of mathematical topics and the continuous study of physics are its leading features. General, theoretical,

and organic chemistry, and chemical analysis, occupy a position next in prominence to mathematics, but of hardly less importance. Options are so arranged that choice may be made between the pursuit of more advanced mathematical and chemical topics; also between shopwork instruction in the use of tools and work in the biological laboratory.

The historical, and other allied subjects, and the modern languages continue throughout the first three years; and the latter, which are of great importance, may be further prolonged if desired. Chemistry may be continued up to the middle of the last year, and mathematics, pure and applied, is required throughout the whole four years. Physics begins with the second year, and by lectures, readings, recitations, and laboratory exercises extends to the close of the course. A large amount of experimental work is performed, and an experimental investigation is undertaken during the fourth year in connection with the preparation of the thesis. At all times it is sought to encourage the spirit of original research, and to impart an understanding of the principles upon which scientific investigation, especially in quantitative measurement, should be conducted.

The advantages offered by the Rogers Laboratory of Physics, notably in the direction of electricity, acoustics, and heat, by the large equipment of apparatus, are somewhat unusual. The study of special topics is greatly facilitated by many valuable libraries to which, by right or courtesy, the students have admission.

First Year.

Same for all Courses.

Second Year.

First Term.

Physics: Lectures.
Mechanics and Acoustics.
Analytic Geometry.
Chemical Analysis.
Theoretical Chemistry.
Descriptive Astronomy.
Political Economy.
German.

Second Term.

Physics: Lectures.
Physical Laboratory.
Acoustics and Electricity.
Differential Calculus.
Microscopy.
English Prose.
German.

Options.

1. Chemistry.
2. General Theory of Equations and Determinants.

Third Year.

First Term.

Physics: Lectures and Laboratory.
Optics or Electricity: Readings.
Integral Calculus.
General Statics.
Physical Laboratory.
Literature.
German.

Options.

1. Chemistry.
   Physiology of the Senses, or Shopwork.
2. Analytic Geometry of Three Dimensions.
   Physiology of the Senses, or Shopwork.

Second Term.

Physical Laboratory: Heat, Electricity.
Optics, Electricity, or Heat: Readings.
Kinematics and Dynamics.
Strength of Materials.
Theoretical Chemistry.
European History.
German.

Options.

1. Chemistry.
2. Advanced Analytic Geometry and Calculus.

Fourth Year.

First Term.

Physical Laboratory.
General Physics.
Advanced Physics: Memoirs, etc.
Principles of Scientific Investigation.
History of Physical Science.
Photography.
Applied Mechanics: Thermodynamics.
Method of Least Squares.

Options.

1. Chemistry.
2. Definite Integrals.

Second Term.

Physical Research.
General Physics.
Advanced Physics: Memoirs, etc.
Differential Equations.
Calculus of Variations.
Discussion of the Precision of Measurements.

Options.

Physiological Measurements.
Physical Laboratory.
Quaternions.
Theory of Potential.

Requirements for Graduation.

The degree, Bachelor of Science, in the course pursued, is given for the satisfactory completion of any regular course of study.

To be entitled to a degree, the student must have passed satisfactory examinations in all the prescribed studies and exercises, and, in addition, a final or degree examination, embracing all the subjects which particularly relate to his course. He must, moreover, prepare a dissertation on some subject included in his course of study; or an account of some research made by himself; or an original report upon some machine, work of engineering, industrial works, mine, or mineral survey; or an original achitectural design accompanied by an explanatory memoir. This thesis or design must be submitted to the Faculty for approval three days before the first degree examination, unless the thesis or design be dependent on laboratory work, in which case it must be presented two days after the close of the respective laboratories.

Students leaving the school before graduation shall be entitled to receive an honorable dismission, if their record for conduct, attention to studies, and scholarship, is satisfactory to the Faculty.

Advanced Courses.

The degree, Master of Science, is awarded for proficiency in complete advanced courses of study of at least one year's duration.

The degrees, Doctor of Philosophy and Doctor of Science, are awarded for proficiency in complete advanced courses of study of at least two year's duration.

The particular course of study which candidates for these degrees wish to pursue must be submitted in writing to the Faculty, and must meet with approval. Occasional short absences, when the time is spent upon professional work by advice of the Faculty, will not be considered as interruptions of the student's residence.

Advanced courses in chosen lines of study, and without reference to the degrees, may be pursued by graduates of the Institute without preliminary examination, or by Bachelors of other institutions, who shall satisfy the Faculty, by examination or otherwise, that they are qualified to take with advantage the course proposed.

Methods and Apparatus of Instruction.

Ordinary Exercises—Instruction is given by lectures and recitations, and by practical exercises in the field, the laboratories, and the drawing-rooms. Text-books are used in many, but not in all subjects. In many branches, the instruction given differs widely from available text-books; and, in several such cases, notes on extended courses of

lectures and laboratory work have been printed, either privately or by the Institute, and are furnished to the students at cost. A high value is set upon the educational effect of laboratory practice, drawing, and field-work.

Written Examinations—Besides oral examinations in connection with the ordinary exercises, written examinations are held from time to time. Near the close of the months of January and May, general examinations are held. After the examinations, the standing of the student in each distinct subject is reported to his parent or guardian. The examinations of January and May form the basis of admonition or advice from the Faculty in the case of students who are not profiting by their connection with the school.

The Instruction in Mathematics—Great importance is attached to the study of mathematics, both as a means of mental discipline and as affording a necessary basis for further instruction in the engineering and other courses.

The four topics following are taken by all regular students :—

1. Advanced Algebra.

2. Solid and Spherical Geometry.

3. Logarithms and Plane Trigonometry, with practical applications to the computation of triangles and the solution of such problems as occur in surveying.

4. Plane Analytical Geometry, including the equations and properties of the point, right line, and circle, and of the parabola, ellipse and hyperbola. (Optional in the General Course.)

Following these, a course in Spherical Trigonometry, including the solution of problems of latitude and longitude, is given to students of Civil Engineering. Students in all the Engineering courses receive instruction in the Differential and Integral Calculus.

In addition to the above, the following topics are given in some courses :—

1. Differential Equations, with applications to problems in Geometry.

2. The Theory of Probability and Method of Least Squares, including the adjustment of observations and the computation of probable errors.

3. Determinants.

As elective work, opportunities are afforded for the study of—

1. Advanced Trigonometry, including De Moivre's Theorem and its applications.

2. The General Theory of Equations, with the solution of higher equations by methods of approximation.

3. Analytical Geometry of Three Dimensions : the equations and properties of the point, right line, and planer, of the sphere, cylinde, and cone, and of the paraboloids, ellipsoides, and hyperboloids.

4. An advanced course in Analytical Geometry and the Calculus.

5. Definite Integrals, with the theory of the Gamma function.

6. Quaternions,

The Instruction in Descriptive Geometry.—The exercises in Descriptive Geometry are of two kinds. In the lecture-room the instruction is given by means of models and diagrams, and also by the use of text-books. In the drawing-room the student is drilled in the construction of such problems as shall illustrate the work of the class-room, and make him thoroughly familiar with this branch of mathematics.

The Instruction in Drawing.—Instruction is given to all regular students in the principles of Geometrical, Mechanical, and Freehand Drawing ; and a large amount of time is devoted to practice in the drawing-room, to enable the student to acquire the necessary skill, and to prepare him for his future work. Drawing is also continued in connection with the professional studies,

The Instruction in Modern Languages.—While the primary object of the instruction in French and German is reading, so that the student may avail himself of foreign works relating to his particular department, much importance is attached to the study of these languages as a means of general training. In either case, a thorough and systematic study of the structure of the language is deemed to be an essential basis. This is, however, accomplished by means of practical work with the language itself, including written and oral exercises, rather than by an abstract study of the rules of grammar. French (see conditions of admission) is continued through one year, and German through two years, for all regular students. In certain courses, especially in IX. there is advanced and special work in French and German, both optional and required. Instruction in the elements of Italian and Spanish is also required.

The Instruction in English.—In this department all regular students receive a course of instruction in English Composition, in the History and Composition of the English Language, in the elements of Inductive and Deductive Logic, and in the History of English Literature. Practice in composition, under the personal supervision and criticism of the instructor, is required, and the principles of good style are further studied and illustrated by the critical reading of standard English authors. In this connection a brief study is made of the history of the English language and the sources of its vocabulary. All regular students are required, in their third year, to attend a course of instruction on some one great period in the history of English literature. More extended instruction in these subjects is given in course IX.

The Instruction in History and Political Science.—All regular students receive instruction in the history of recent times, followed by a course in general European History, and a course in English and American Constitutional History. A course in Political Economy is given to all regular students. Students in the General Course receive more extended instruction in History and Political Science.

The Instruction in Chemistry.—All students who are candidates for degrees attend a course of lectures on Inorganic Chemistry, illustrated by experiments, and perform actual experimental work in the laboratory for general chemistry. The lectures are intended to prepare the student for his work in the laboratory, and to emphasize the facts which he there learns. In the laboratory the student receives instruction in chemical manipulation, and performs a series of experiments designed to illustrate the properties of the more important elements and the laws of chemical action. In connection with the lectures in Inorganic Chemistry, the elements of theoretical chemistry are taught; and the student has practice in the solution of stochiometrical and other chemical problems. The study of the theory of the subject is continued by a more advanced course of lectures and recitations, in which are presented the prevailing theoretical views as to chemical action, the constitution and classification of chemical compounds, as well as certain portions of molecular physics which bear directly upon chemical theories, especially in the matter of thermo-chemistry.

The instruction in Analytical Chemistry extends through two or more years. Each student is given a desk in the laboratory, which is open to him at all times, and he receives personal instruction. Regular students have analytical work assigned them with particular reference to the course they are pursuing. This work is so arranged that they obtain experience in a great variety of methods and processes, and are thus prepared to undertake any chemical analysis. The more industrious students, and those who work extra time in the laboratory, have the privilege of supplementing their regular laboratory course with special work and instruction if they desire it. Special students may select any branch of analytical work for which they are qualified.

Particular attention is given to volumetric analysis. A special laboratory is fitted for this work, and the students are taught to graduate and calibrate the various instruments of measurement.

As an introduction to original work, each student is required to undertake a critical examination of some process of analysis, to determine its limits of accuracy under various conditions, and to make a written report thereon.

The special instruction in the laboratory is supplemented by lectures upon methods of analysis and manipulation; and the current chemical literature in English, French, and German is reviewed by the students, and subsequently discussed in the class-room under the direction of one of the professors.

The instruction in Sanitary Chemistry consists mainly of laboratory work, and special laboratories have been equipped for the purpose. For all who choose to pursue this subject, a minimum amount of work is laid out, consisting of practice in the methods commonly used in the chemical examination of air and water, of milk and butter. For those who wish to take a more extended course opportunity is afforded for the critical study of other methods of analysis, for the examination of other articles of food, and for the investigation of a variety of sanitary problems in which chemical questions are involved.

Industrial Chemistry is taught by a course of lectures, and by work in the laboratory of industrial chemistry. A full description of the most important technical applications of chemistry is given in the lectures. A part of the lectures is given by persons actively employed in carrying out the processes which they describe. In the industrial laboratory the students prepare chemical products from raw materials. They also undertake the preparation of pure chemicals. They are taught fractionation and distillation. Particular attention is paid to the preparation of dyes and mordants. A full course of instruction in bleaching and dyeing is given. It includes scouring, bleaching of cotton and wool, and the dyeing of yarn and cloth. The students are taught how to make comparative dyeing and printing tests, and qualitative tests to determine the dyes present upon fibers. The students also become familiar with many of the most useful methods of commercial analysis. The laboratory instruction is supplemented by frequent excursions to manufacturing establishments, where the practical working of chemical industries can be examined.

The instruction in Organic Chemistry consists of lectures and laboratory work. The theories of organic chemistry are discussed, and the practical applications of these theories described. The work in the laboratory consists of ultimate analysis, preparation of organic products and original research. The researches undertaken in this laboratory deal for the most part with those problems in organic chemistry which have a distinctively technical bearing. Ample opportunities are afforded for the prosecution of investigations in the domain of pure chemistry.

The instruction in Chemistry is designed primarily for those who are candidates for the several degrees of the institute, and for such special students as are looking to chemistry as a profession, and are following, in the main, the courses laid out for the regular students. These special students are required to study French and German as a part of their course, and are held to the same examinations in the subjects which they pursue as are the regular students. In addition, the institute desires to make available all the facilities of the lecture-rooms and laboratories to teachers who wish to perfect themselves in chemistry, and to persons of mature years who are engaged in technical pursuits, and who wish to acquire an accurate knowledge of the science. Such persons may be admitted without formal examinations, on satisfying the professors in the department that they are competent to pursue to advantage the subjects chosen.

The Kidder Laboratories of Chemistry afford accommodations for five hundred students. The chemical department occupies fourteen laboratories, two lecture-rooms, a reading-room and library, balance-room, offices, and supply-rooms: in all, twenty-three rooms. The laboratory for general chemistry has places for two hundred and eighty-eight students, and is very completely equipped for instruction in elementary chemistry. The analytical laboratory can accommodate one hundred and fifty students, and possesses every convenience for accurate and rapid analytical work. The organic laboratory has places for thirty students. Conveniences are afforded for conducting offensive and dangerous operations in the open air, or in a separate room. The sanitary laboratories contain places for sixteen students. They possess a very complete outfit for the analysis of air and water, and for the investigation of sanitary problems. The laboratory for industrial chemistry accommodates sixteen students. It contains jacketed kettles, a

centrifugal drier, drying chambers, stills, presses, and numerous other pieces of apparatus needed to perform chemical operations upon a considerable scale. In connection with this laboratory is a room devoted to textile coloring, furnished with kettles, water-baths, drying-room, and various working models of machines used in this branch of applied chemistry. Kidder Hall has a seating capacity of one hundred and eighty, and is arranged with special reference to the delivery of experimental lectures. In addition, there is a small lecture-room, seating thirty. The lecture-rooms contain valuable cabinets of specimens for purposes of illustration. The balance-room is supplied with twenty-two balances.

The William Ripley Nichols Library of Chemistry, numbering more than twenty-eight hundred volumes and two thousand pamphlets, is kept in the reading-room of the department. This library contains complete sets of most of the important chemical periods. It is primarily designed to aid in the instruction, but is open to all persons who desire to consult it.

The Instruction in Physics.—This begins with a series of lectures attended by all regular students, in which the whole subject of Physics is discussed. The various branches are treated both mathematically and experimentally. In all cases, the theoretical discussion of a question is followed by a full account of its practical applications.

The institute possesses an extensive and rapidly increasing collection of physical apparatus, which has recently been materially increased by a gift from the late Dr. Robert E. Rogers, of his valuable cabinet of optical and electrical instruments.

In addition to the courses of general lecture-room and laboratory exercises in Physics, which are required of all regular students, various special courses of lectures, readings, and laboratory exercises in Optics, Acoustics, Heat, and Electricity, are provided for those making a specialty of Physics. Students pursuing these courses gain a familiarity with standard works on the various branches of Physics, in both their own and foreign languages. The subject of Photography, including its applications to micro-photography, spectrum photography, and the various photo-mechanical processes, will be discussed in a series of lectures accompanied by practical exercises in the photographic laboratory. Instruction is also given in Microscopy, and in the use of the lantern as an instrument of demonstration in the lecture-room. A course of lectures and laboratory instruction in Calorimetric Measurements and allied subjects has been instituted, and the course in general Electrical Measurements is undergoing continual extension.

The Rogers Laboratory of Physics.—All regular students enter upon a general course of experimental work in this laboratory after the lecture course on Physics. The work is designed to strengthen the student's grasp of the laws and phenomena of that science, and to impart to him a knowledge of methods and instruments used in measurement, and of the mathematical discussion of experimental results. The laboratory work consists almost exclusively of quantitative measurement. The earlier and simpler work serves chiefly to train the student in the use of methods or instruments which are employed as accessories later. To this succeed experiments on the mechanics of solids, liquids and gases, each illustrating a method by which some physical law or constant is determined. Work in optics follows; and heat and electrical measurements occupy the remaining and more difficult part of the course, more advanced instruction in both, however, being provided for.

Accurate work is required throughout; and in connection with the use of instruments of precision, especially in the more advanced measurements, the student's attention is particularly directed to the study of possible sources of error, and to the discussion of the effects of these on the results obtained.

The particular line of work assigned to each person is determined, to some extent, by his course in the school; and the instruments which he studies are often such as he will be called upon to use in later technical work. In some courses, *e.g.*, Physics, Electrical Engineering and Chemistry, work of a more advanced scientific or technical nature is carried on. Original investigation is encouraged as far as possible, and the result has been a considerable number of published memoirs.

The library of the department contains the standard works upon various branches of

Physics. It is especially full in those relating to electricity, and all new works of value on that subject are added as they appear. Most of the leading scientific and technical periodicals devoted to Physics are regularly received, and are accessible to students.

The Instruction in Electrical Engineering.—As a foundation for subsequent work, thorough instruction is given in the theory of electricity. An extended course of lectures is devoted to the consideration of the various technical applications of electricity to land and submarine telegraphy, the telephone, electric lighting and the electrical transmission of power. Instruction is given by lectures and laboratory exercises upon the processes of photometry, especially as applied to the measurement of electric lights. Advanced instruction in electrical measurements, including work with dynamo-electric machinery, together with a course on the electrical testing of telegraph lines, is provided. The subjects of construction, specifications and contracts also receive attention.

In the latter part of the course each student prepares and reads before his class an essay on some electrical process, instrument or system, or other professional topic. These are written after a study of recently published papers and memoirs, and often embody also the results of experimental work by the student. They are intended to familiarize the class with the topics presented, and to give experience in independent study and in the preparation of original scientific papers. The work is also of particular advantage to those who intend to become teachers.

Besides the work done by the regular staff of instruction of the Institute, special teaching will be given by gentlemen who are professionally engaged in various departments of Electrical Engineering or especially conversant with certain branches of applied electricity. During the past year such instruction has been given by the following gentlemen:—

Mr. George W. Blodgett, Electrician of the Boston and Albany Railroad, on the Application of Electricity to Railway Signalling ; Mr. J. Rayner Edmands, of the Harvard College Observatory, on the Establishment and Distribution of Time ; Professor Elihu Thomson, Electrician of the Thomson-Houston Electric Company, on the Construction and Design of Dynamo Machines ; Mr. A. C. White, late of the Western Edison Electric Light Company, on Methods of Wiring for the Distribution of Electricity ; Mr. Edward Blake, of the Sprague Electric Railway and Power Company, on Electro-Motors ; Mr. C. J. H. Woodbury, of the Manufacturers' Mutual Fire Insurance Company, on Electric Lighting in its Relation to Fires and Fire Insurance ; Mr. C. A. George, on Municipal Fire Alarm Systems. It is expected that these courses will be still further extended during the current year.

The Institute possesses several dynamo machines of various patterns, both for arc and incandescent lighting, which are devoted to purposes of instruction.

The Instruction in Theoretical and Applied Mechanics begins with the study of the Composition and Resolution of Forces, the general laws of Kinematics and Dynamics, mathematically discussed, the principles governing the determination of the stresses in the different members of trusses, centre of gravity, moment of inertia, and the ordinary principles of the strength of materials.

The more advanced part of this instruction embraces the completion of the study of Strength of Materials, including laboratory work, Theory of Elasticity, main principles of the Stability of Arches and Domes, and special study of Dynamics.

The methods of the differential and integral calculus are freely used whenever they are the most convenient.

The Laboratory of Applied Mechanics.—The object of this laboratory is to give to the students, as far as possible, the opportunity of becoming familiar, by actual test, with the strength and elastic properties of the materials used in construction.

It is furnished with the following apparatus :—

1. An Oslen testing-machine of fifty thousand pounds capacity, capable of determining the tensile strength and elasticity of specimens not more than two feet long, and the compressive strength of short specimens.

2. A testing-machine of fifty thousand pounds capacity, capable of determining the transverse strength and stiffness of beams up to twenty-five feet in length, as well as of many of the framing joints used in practice.

3. Machinery capable of determining the strength, twist, and deflection of shafting when subjected to such combinations of torsional and transverse loads as occur in practice, and while running.

4. Machinery for making time-tests of the transverse strength and deflection of full-sized beams.

5. A machine for testing the tensile strength of mortars and cements.

6. Apparatus for testing the strength of ropes.

7. The accessory apparatus needed for measuring stretch, deflection, and twist.

The classes are divided into small sections when making tests with the machines.

All the experiments are so chosen as to make the student better acquainted with the resisting properties of materials, many of them forming part of some original research. Those on transverse strength and stiffness have also determined certain constants for use in construction, which had not previously been determined from tests on full-sized pieces.

The Instruction in the Mechanic Arts.—Practical instruction in the nature of the materials of construction, and in the typical operations concerned in the arts, is considered a very valuable adjunct to the theoretical treatment of professional subjects. Mechanical laboratories have been provided, and furnished with the more important hand and machine tools, so that the student may acquire a direct knowledge of the name of metals and woods, some manual skill in the use of tools, and a thorough knowledge of what can be accomplished with them. These laboratories are now located in the building on Garrison Street, and are equipped as follows :—

The carpenter, wood-turning, and pattern-making departments contain 40 carpenter's benches, 2 circular-saw benches, a swing-saw, 2 jig-saws, a buzz-planer, a boring-machine, 36 wood-lathes, a large pattern-maker's lathe, and 36 pattern-maker's benches. The foundry contains a cupola furnace for melting iron, 2 brass furnaces, and 32 moulder's benches. The forge shop contains 32 forges, 7 blacksmith's vises, and 1 blacksmith's hand-drill. The machine-shop contains 23 engine-lathes, and 14 hand-lathes of recent approved patterns, 2 machine drills, 2 planers, a shaping-machine, a universal milling-machine, a grinding-lathe, and 32 vise-benches arranged for instruction in vise-work.

The Instruction in Civil Engineering is given by means of lectures and recitations, and by practice in the field and in the drawing-room. Visits are also made to works of interest and to manufacturing establishments of various kinds.

In surveying, the use of the various instruments is taught mainly by actual work in the field, covering the different operations involved in land, topographical, hydrographical, railroad, city, and mining surveying. The work in the drawing-room consists in representing upon paper the surveys made in the field, followed by topographical and map drawing; in topographical and other drawing, in connection with the field-work in railroad location; in the production of finished plans from direct measurement of actual engineering structures; and in making complete designs and working-drawings of bridges and other structures, plans for sewerage and water-supply, etc.

The course in Roads and Railroads includes the survey, location, construction, and equipment of railroads; and the laying-out, building, and maintaining of town and county roads, and of city streets and pavements. In addition to the work in the class-room, an actual railroad survey and location, several miles in length, is made each year upon such ground as shall best illustrate the actual problems occuring in practice. Advanced courses (optional) are also given, embracing the subjects of railroad management and transportation, rolling-stock, motive-power, signals, etc.

The course in Hydraulic Engineering embraces the subjects of theoretical hydraulics with its practical applications,—hydrology, rivers and canals, water-supply, water-power, foundations, coast and harbor works, and irrigation. The practical application of the principles of hydraulics is illustrated by numerous examples; and in hydrometry the

student is made thoroughly familiar with the best methods, by actual practice in gauging rivers with instruments of various kinds, which have been provided for the use of the classes. The subjects of hydrology and irrigation are considered in detail, with reference to the conditions found in the United States. Special attention is given to the sources and supply of water, to its flow in natural and artificial channels, and to the methods of collecting, storing, filtering, raising, and distributing water for domestic purposes, with practical details for carrying out such works. A particular study is also made of the control and improvement of rivers, of the construction of locks, dams, and canals, and of the utilization and distribution of water as a motive-power, excursions being made to the cities of Lowell, Lawrence, and Holyoke, for practical illustrations of this branch of engineering. Under coast and harbor works are considered the design and construction of harbors, docks, sea-walls, breakwaters, and jetties, the maintenance of channels, and the protection of coasts. The course in Sanitary Engineering embraces the study in detail of the house, with its apparatus, the disposal of sewage by surface or sub-surface irrigation for isolated buildings, the collection and removal of sewage in the larger towns, sanitary drainage for cities, and drainage and irrigation for agricultural purposes. Frequent opportunities are given to the student for the inspection of actual examples of sanitary engineering, and a study is made of the questions of the day in relation to public health.

The course in Principles of Construction embraces a study of the methods of determining the stresses in bridges and roofs, and of investigating the stability and strength of piers, abutments, arches, retaining-walls, and similar structures. The course in Bridges and Roofs consists in a detailed study of the different structures of this class, with reference to economy of material, methods of proportioning parts, and the details of design. Parallel with it goes the work in the drawing-room, in which the student is required to make complete designs and working-drawings, with blue prints, for several structures of this kind. The materials used in engineering are studied in the courses on the Strength of Materials and the Metallurgy of Iron; and, in addition, further study is devoted to this subject in connection with the other courses, each material being taken up in connection with the structures in which it is most extensively applied. A laboratory for cement testing, fitted with all the necessary apparatus, is thus made extensive use of by the students in Sanitary and Hydraulic Engineering. The study of Specifications and Contracts is taken up in connection with each of the special courses, and a variety of actual specifications are studied in detail, each in its proper place. The course in Geodesy and Practical Astronomy includes the study of descriptive, spherical, and practical astronomy, and of the mathematical and physical principles of geodesy, with practice in some of the simpler geodetic field operations.

In the summer vacation following the third year, students taking the topographical option are required to attend a summer course in Topography, Geology, and Geodesy, during from four to six weeks in the early part of the summer. This course is held at some convenient and suitable point in the country, and its object is to give the students opportunity for more extended and more continuous field practice in these branches than is possible during the term. The work done consists of a topographical survey of a certain district, with field practice in geodesy and geology. The course is open, without extra charge for tuition, to all students in the department who have completed the third year. as well as to properly qualified students in other departments. Persons not connected with the Institute may also be permitted to attend, upon giving satisfactory evidence of being properly qualified, and upon payment of the tuition fee of $25.00.

By the kindness of many active members of the profession, and especially through the courtesy of Mr. W. H. Barnes, General Manager of the Boston & Albany Railroad, and of Mr. James T. Furber, General Manager of the Boston & Maine Railroad, the classes are able to inspect a great variety of engineering works, and to carry on field operations in specially favorable localities. The help thus received has been of great value.

In addition to the regular lectures of the school, many prominent engineers in the active practice of their profession have consented to deliver occasional lectures on subjects with which they are specially familiar.

During the past year lectures have been given by Mr. Eliot Holbrook, on Railway Maintenance and Equipment; by Prof. Arthur T. Hadley, on Railroad Economy; by Dr. John S. Billings, on Public health; and by Mr. E. S. Philbrick, on Matters of Engineering Practice. A course of Emergency Lectures, on the treatment of accidental injuries, by Dr. R. W. Lovett, was also given before the students. Students in this department also attend the lectures of Mr. Geo. W. Blodgett, on Railway Signaling.

The Instruction in Mechanical Engineering is given by means of lectures and recitations, and by practice in the drawing-rooms and in the mechanical engineering laboratory. Frequent visits, also, are made to machine-shops and manufacturing establishments to witness machinery in operation, and manufacturing processes in addition to those which can be seen at the Institute itself.

The laboratory work, in its earlier portions, is devoted to some of the more simple experiments, such as will impart to the students a familiarity with the manner of running the engines, taking indicator cards, and using the other apparatus in the laboratory. The latter laboratory work takes very largely the form of original research; and it is intended that the students of this laboratory shall, under suitable direction, undertake the experimental investigation of a number of important engineering problems.

A large amount of drawing is done by the students throughout their course in connection with their regular work, drawing for mere practice ceasing at the end of the first year. A style is adopted that is believed to be a good one, and is adhered to throughout; and early in their course the students are taught to use the "Blue process."

Besides the teaching done by the regular corps of instructors, lectures upon special subjects are given by gentlemen actively engaged in the profession. During the last school year, lectures were given by Mr. H. A. Hill, on the Indicator; Mr. James N. Lauder of the Old Colony Railroad, on the Locomotive; Mr. Henry R. Towne, President of the Yale & Towne Co., on Shop Management; Mr. Edward Burgess, on Naval Architecture; and Mr. Geo. H. Barrus, on Cylinder Condensation.

The Laboratory of Mechanical Engineering.—The objects to be accomplished by this laboratory are the following:—

1. To give to the students practice in such experimental work as they are liable to be called upon to perform in the practice of their profession, as boiler and engine tests, pump tests, calorimetric work, measurement of power, etc.

2. To give to the students practice in carrying on original investigations on mechanical engineering subjects, with such care and accuracy as to render the results of real value to the engineering community.

3. By publishing, from time to time, the results of such investigations, to add gradually to the common stock of knowledge.

The laboratory contains as a portion of its equipment,—

1. An eighty-horse-power Porter-Allen engine, by which power is also furnished to the new building and to the mining department.

2. A sixteen-horse-power Harris-Corliss engine, used almost entirely for experimental purposes: this is furnished, in addition to its own automatic cut-off governor, with a throttle governor, so arranged that either can be used, the former being in addition so constructed that the speed of the engine can be varied at will.

The exhaust of each engine is connected with a surface condenser, and thence with a tank on scales, so that the water passing through the engines can be weighed.

3. An eight-horse-power steam engine used for giving instruction in valve-setting, etc.

4. Three surface condensers, one of which is arranged in sections, so that the condensing water can be made to traverse the length of the condenser once, twice, or three times, at the option of the experimenter.

5. Machinery for determining the tension required in a belt to enable it to carry a given power, at a given speed, with no more than a given amount of slip.

6. Two brakes so constructed that a given amount of work can be put at will on either engine, and in such a manner that this work can be accurately measured; also two other portable brakes.

7. A steam-pump so arranged as to enable the students to make pump tests, indicating both the steam and the water cylinder, weighing the exhaust steam, and also the water pumped.

8. A six-inch Swain turbine-wheel so arranged that it can be run under a head of fifteen feet, and that experiments can be made on the power exerted, the efficiency, etc., under different gates.

9. Three calorimeters.

10. A dynamometer.

11. Cotton machinery as follows, viz.:—A card, a drawing-frame, a speeder, a fly-frame, a ring-frame, and a mule.

12. Apparatus for testing injectors.

13. A mercurial pressure column.

14. A mercurial vacuum column.

15. Apparatus for determining the quantity of steam issuing from a given orifice under a given difference of pressure.

16. Apparatus for testing dynamometers.

17. A good supply of indicators, gauges, thermometers, anemometers, and other accessory apparatus.

18. Four horizontal tubular boilers. Another boiler, a forty-horse-power Brown engine, a number of looms, and other apparatus in the mechanical laboratories on Garrison Street, are available for the purpose of experiment.

As examples of the work done in the laboratory, the following experiments are enumerated:—Tests of the evaporative power of boilers; tests of the effects of different cut-off, compression, back pressure, speed, etc., of engines under constant or variable loads; calorimetric tests; dynamometric measurements; investigation of the tension required in a belt to carry a given power, at a given speed, with no more than a given amount of slip; experiments on the efficiency of condensers under different conditions; on the efficiency of a turbine, etc.

The Mining and Metallurgical Laboratories.—The aim of these laboratories is to furnish students the means for studying, experimentally, various processes of ore-dressing and smelting, and at the same time to enable them to gain an idea of what is required of a miner or metallurgist. To this end, the apparatus has been chosen with a view of illustrating, as far as possible, the principles of the more important machines and furnaces which are used in mining and metallurgy.

The metallurgy of lead, copper, gold, and silver has been chosen as the best suited for laboratory illustration; production of iron and steel in quantity is prohibited by the size of the plant requisite, and by the large amount of ores and fluxes necessary to put this into operation.

The experimental work of the laboratory is carried on by the students under the immediate charge of an instructor. A sufficiently large quantity of ore is assigned to each student, who first examines it for its component minerals, sorts and samples it, and determines its character and value by analysis and assays, and makes such other preliminary examinations as serve to indicate the proper method of treatment. He then treats the given quantity, makes a careful examination of the products at each step of the process, ascertains, wherever practicable, the amount of power, water, chemicals, fuel and labor expended, and thus learns approximately the effectiveness and economy of the method adopted. He learns, also, the value of chemistry as a check upon metallurgical work. Each student is assisted in working his ore by his classmates, each of whom has an opportunity in turn to manage the machines and furnaces.

The Institute does not claim that this laboratory is in any sense of the word a substitute for the works. What is claimed is, that it prepares students to go into works, and to profit by them. The spirit of investigation which is developed is of great advantage to the student.

The mining laboratory consists of three parts—milling-room, furnace-room, and assay-room—with ample storage-vaults, supply-room, and toilet-room attached.

The milling-room is supplied with four suites of milling-apparatus :—

I. A three-stamp battery, a set of amalgamating-plates, a mercury-saver, a Fruevanner for concentrating tailings, a settling-tank, and a centrifugal pump.

II. A Blake challenge crusher, crushing-rolls with automatic sizing screens, a Richards-Coggin separator, a spitzkasten, two Harz-Mountain jigs, an Evans table or rotary-buddle, a settling-tank, and a centrifugal pump.

III. A set of four amalgamating-pans, 30, 18, 12, and 8 inches in diameter respectively, also a 36-inch settler, and a little automatic kieve for separating mercury from pulp.

IV. A set of three 40-gallon leaching-vessels, a set of four 8-gallon leaching-vessels, and two dynamos for deposition of metals.

This laboratory contains also the following auxiliary apparatus : A steam-engine, a Bogardus mill, a Root blower, a Sturtevant dust-fan and blower, drying-tables, and four Morrell agate mortars.

The furnace-room contains a water-jacket blast-furnace, a copper-refining furnace, a reverberatory lead-smelting or agglomerating furnace, two roasting-furnaces, furnaces for cupellation, furnaces for fusion, a blacksmith's forge, a melting-kettle, retorts, etc. The assay-room contains ten crucible furnaces, 12 x 12, all of which are jacketed with iron shells to insure good draught, stability, and durability; also two muffles 4 x 7, one muffle 3 x 6, four muffles 7 x 12, one muffle 8 x 15. These furnaces are all provided with ample flue capacity and abundant draught. This room contains also six pulp-balances, six flux-balances, five button-balances, and desks for fifty students.

The Institute is from time to time receiving ores of gold, silver, lead, copper, nickel, antimony, etc., from various localities. These ores are worked, and reports sent to those who contribute them ; and it is expected, that, by the coöperation of those who wish to have examinations made, the laboratory will continue to receive the necessary amount and variety of ores.

To bring the mining students into closer acquaintance with their profession, excursions are organized for visiting mines, mills, smelting-works, and geological fields. These excursions take place as often as once in two years; and, since the year 1870, excursions have been made to Colorado, Lake Superior, Virginia, Vermont, Pennsylvania, Lake Champlain, New Brunswick, and Nova Scotia. Shorter excursions of a day or two at a time are made while the school is in session.

The valuable scientific library of the late Prof. Henry D. Rogers of the University of Glasgow, presented to the Institute by Mrs. Rogers, is accessible to the students in geology and mining.

The Instruction in Zoology and Palæontology, including the history of ancient animal life and the study of the distinctive and characteristic fossils of the different formations, is given as a necessary foundation for the further study of Geology. The aim of the course is to give the student a practical acquaintance with the structure of the characteristic families and orders of living and extinct animals, and, by a judicious selection of examples, to familiarize him to some extent with the forms which characterize different periods.

The handling and drawing of specimens by the student are essential features of the method of instruction. The lectures of the instructor are devoted largely to explanatory demonstrations of the specimens which the students have studied and drawn.

The Museum of the Boston Society of Natural History is used in this course, and also a laboratory collection of recent and fossil animals belonging to the society, and selected with special reference to the needs of students.

The Instruction in Mineralogy—Crystallography is taught with the aid of models, diagrams, and a series of crystals. In Descriptive Mineralogy, specimens are freely used, an example of each of all the more important species being placed before each student, while a collection of typical specimens is always open to students. The collection in this department is supplemented by that in the museum of the Boston Society of Natural History, as explained in the next section. In Determinative Mineralogy, students are taught to identify minerals by their crystallization and physical properties, as well as by their blowpipe or chemical characters. The instruction in Blowpipe Analysis is given in a separate laboratory, and is supplemented by sufficient practice to insure familiarity with the methods.

In the spring, several excursions are made to interesting mineral localities.

The Instruction in Physical Geography and Geology.—The topics of these closely allied sciences are taught in the order of their logical succession, hence the work done in one class is a preparation for the next.

I. Physical Geography.

The student who has studied Physical Geography at a good preparatory school will not find this course a repetition of what he has already received. The position of the study as a general science is recognized and fitly taught, while its relations to the progress and destinies of mankind receive that special attention they should have in a technological institution. Much of the success which attends engineering, commerce, manufacturing, and many other branches of industry, is in a measure dependent upon the control or utilization of great terrestrial forces. It is, therefore, just to claim that a scientific knowledge of efficiency of these forces in nature, and of the physical laws of their action, is eminently important.

These forces are likewise geological agents, and it is through them alone that the student can interpret the structure of the earth. It is in this connection that Dynamical Geology is taught as directly preparatory to the courses which follow.

The instruction consists essentially of a course of lectures, but at each exercise questions are asked, to which answers are given either orally by a few, or are written by all the members of the class. The students are required to take notes and present them for examination. The lectures are amply illustrated.

II. Structural Geology.

This division includes a systematic course in Lithology, in which observation or laboratory work is combined in an unusual degree with oral instruction. At each lesson a tray containing a typical hand-specimen of every type to be studied is placed before each student; and the lessons consist largely in the examination, testing and description of the specimens by the students themselves, the instructors simply directing and supplementing the work of the class. The collections in this department are extensive, and specially adapted to the laboratory method of instruction; and a complete series of typical rocks is accessible to students at all times. The principal structural features characterizing large masses of rocks, embracing stratification, joint-structure, faults, folds, slaty-cleavage, veins, dikes, etc., are taught as practically as circumstances will allow. The unusually favorable opportunities which the local geology of Boston presents for the illustration of these topics are utilized by means of frequent field lessons. The instruction in Chemical Geology is also introduced here, and embraces the formation, alteration, and decay of rocks, the origin of vein-stones and ore deposits, of rock salt and mineral waters, and of coal and petroleum.

III. Historical Geology.

It is intended to give all the students in this branch a good general knowledge of the physical history of the earth. That the technical applications of geological knowledge may be suitably taught, the students are grouped into three classes.

One class is composed of those who are in the department of Civil Engineering. With these, special attention is given to those portions of geological history which determined the topographic and hydrographic features, with which their professional labors may be more or less associated.

Another class is for the students in the departments of Mining Engineering and Chemistry. Particular attention is here given to the geological history and the modes of occurrence of ore deposits and other mineral resources. This, added to portions of Structural and Chemical Geology previously taught, completes the class-room instruction in Economic Geology.

A third class includes the students in Natural History and in the General Course. With these more time is devoted to the life of the past ages, to the relations of life to physical conditions, and to the geologic events which led to the present distribution of beings upon the earth. To be admitted to this class the student must have had the requisite instruction in Biology and Zoölogy.

The instruction combines both lectures and recitations. The collections at the Institute are for teaching and not for exhibition. The classes are conducted with the belief that the more intimate the students become with the natural objects and features, the better the instruction. There are serious obstacles to a liberal amount of field practice, but every available opportunity is improved, and the amount is steadily increasing. There is a valuable geological library.

In addition to the efficient collections in the Rogers Building, the students in this department have access at all times to the extensive and valuable mineralogical and geologieal collections of the Boston Society of Natural History. These are very conveniently placed, and have been arranged with special reference to the needs of students, each division of mineralogy and geology being separately and fully illustrated in the order in which it is taken up in the Institute course.

The Instruction in Climatology.—The elements of physical science which are fundamental in the study of Meteorology are taught in the course in Physics, and in the physical laboratory the students have some practice with the ordinary meteorological instruments. The course in Climatology is introduced by a general outline of Meteorology, and concluded by a discussion of the known influences of climates upon the nature and distribution of plants and animals, upon the resources of countries, and upon the health, vigor, and prosperity of communities and nations.

The Instruction in Biology begins the second year with a course of lectures, recitations, and laboratory exercises in General Biology. Attention is given to fundamental facts of life and living matter, protoplasm, cells, tissues, and organs; and these are illustrated upon representative forms of animal and vegetable life, such as the fern, earthworm, yeast-plant, amœba, moulds, bacteria, etc. Afterwards higher forms, like the lobster, clam, seed-plant, frog, and rabbit, are carefully dissected and studied. Stress is laid not less on physiological than anatomical facts and theories, and painless studies of the living specimen are regarded as of prime importance. This general introductory course is followed by more special work in comparative anatomy and embryology (chiefly of vertebrates), accompanied likewise by practical laboratory studies, with dissections, the histology of the embryo chick, etc. The third year in Biology is devoted to lectures, recitations, laboratory work, and excursions in Zoölogy and Botany.

In the fourth year comparative physiology and histology are taken up, and pursued till graduation. They are taught experimentally in the laboratory, and by lectures and recitations. Physiological chemistry also receives attention. Lectures are given during this year upon higher biology, including topics like natural selection, mimicry, evolution, the germ theory of disease, heredity, and the history of the biological sciences. A biological-journal club, to which the more advanced students are admitted, has been found helpful as a means of keeping abreast of current progress, and in giving practice in bibliography.

Students of biology have also valuable privileges in connection with the Boston Society of Natural History, of which the museum, the library, etc., are freely accessible.

The Biological Laboratory is a large room on the first floor of the Rogers Building. It is well lighted, and furnished with tables for microscopical work, for dissection, and for the similar operations of physiological chemistry. Every student is supplied with a Zeiss or Hartnack microscope, a work-table and a locker. The laboratory instruments include Thoma and Schanze microtomes, a long-roll kymograph, Du Bois-Reymond induction machines, and a rotating drum for smoked paper, a moist chamber, pendulum myograph, bacteriological apparatus, etc. Frog-tanks and aquaria are also provided. The biological library is in the laboratory, and includes all the ordinary text-books and works of reference. It has been much enlarged during the past year, both by gifts and by purchase.

The Instruction in Architecture.—The instruction in this subject is practical as well as theoretical. Besides the scientific study of construction and materials, it comprises the study of building processes and of professional practice, as well as that of composition and design, and of the history of the art. It is so arranged as to meet the wants, both of those who commence their professional studies at the beginning, and of experienced draughtsmen who desire to make up deficiencies in their training, or to qualify themselves for undertaking the responsibilities of practice.

The more strictly professional work begins with the study of the Five Orders and their applications, and of Architectural History ; while, with constant practice in drawing, the students are familiarized with the material elements of their future work by a course in practical construction, illustrated by lectures, problems, and by visits to buildings. During the following years the subject of specifications and contracts is thoroughly gone over ; and problems in construction of all kinds serve to fix in the memory the principles already learned, and to supplement them by more advanced instruction.

The students are continually practised in architectural design. Each set of drawings is examined, and criticised before the classes. Instruction is also given in sketching in black and white, and water-color ; and evening classes are held during the winter for drawing, both from the life and from the cast, to which all students in the department are admitted.

The Boston Society of Architects has established two prizes of the value of fifty dollars each, given in books, for students who, at the end of the year, exhibit the best work.

The Architectural Museum.—Several thousand photographs, prints, drawings, and casts have been collected for this department, by means of a special fund raised for the purpose. To these collections large additions have been made, mostly by gifts. Models and illustrations of architectural detail and materials are arranged in the rooms of the the department. The chief part of the collection of casts of architectural sculpture and detail belonging to the department have been deposited in the Museum of Fine Arts, together with the architectural collections belonging to the Museum. The students of the department have free access to them at all times ; and as the museum building is close at hand, no inconvenience results from the change. The space thus gained is filled with specimens of metal-work, tile-work, glass-work, and wood-work, partly purchased, but mostly deposited with the department by the manufacturers, forming a museum of sanitary and building appliances. The library of this department contains technical works and many periodicals, both American and foreign. The publications of the Royal Institute of British Architects, and of the Société Centrale des Architectes in Paris, are presented by the authorities of those institutions.

Libraries—The Institute possesses an increasing general library ; and each department has, in its own reading-room, its separate working-library of reference. A valuable addition to these has recently been received by a gift, from Mrs. Rogers, of several hundred books and pamphlets from the library of the late President William B. Rogers. These departmental libraries, which are of the greatest value to students, are intended to contain a careful selection of the best text-books, special treatises, monographs, etc., and the more valuable periodical publications, in the subjects germane to the work of the department. They are accessible to all students ; and a certain valuable experience in the use of them is acquired before the completion of the regular courses, either incidentally to the preparation of theses, or in connection with lectures or recitations.

The Boston Society of Natural History grants to the students of the Institute the full use of its valuable library. The unusual facilities of the Boston Public Library, of nearly 500,000 volumes, are at the disposal of all students of the Institute. The collections of this library are of exceptional value, and contain the best scientific, literary, and technical publications of various countries, whether standard or special treatises, periodicals, or works of more purely literary or historical value; and new books are promptly bought on proper application to the authorities of the library.

Many libraries of scientific societies, of individuals, and of private corporations, rich in the complete sets of the scientific periodicals of all countries, and of the publications of leading scientific societies throughout the world, are, through the courtesy of the owners, open to advanced students of the Institute.

Professional Success.

The following list shows the positions occupied by the Graduates of the School of Industrial Science :—

Ellery C. Appleton, Assistant Engineer, Burlington & Missouri River Railroad.

Eli Forbes, Chemist at the Lancaster Mills.

Chas. E. Greene, A. M., C. E., Professor of Civil Engineering, University of Michigan.

Albert F. Hall, Draughtsman, in the employ of the George F. Blake Manufacturing Company.

William E. Hoyt, Chief Engineer of Buffalo, Rochester & Pittsburg R.R. Co.

Robert H. Richards, Professor of Mining and Metallurgy, Massachusets Institute of Technology.

Bryant P. Tilden, Chief Engineer, Jamestown & Northern R.R.

William H. Baker, Assistant Engineer, New Mexico Division A., T. & S.F.R.R.

J. Rayner Edmands, in charge of Time Service at Harvard College Observatory.

Channing Whitaker, Mill and Steam Engineering, Construction, Consultation, and Expert Work, Lowell, Mass.

Charles R. Cross, Thayer Professor of Physics, Massachusets Institute of Technology.

Charles W. Hinman, Mass., State Inspector of Gas.

Sampson D. Mason, Principal Assistant Engineer, Northern Pacific Railroad.

N. Frederick Merrill, Professor of Chemistry, University of Vermont.

Edmund K. Turner, Chief Engineer, Fitchburg Railroad.

Laurence F. J. Wrinkle, Mining Engineer, Virginia, Nev.

Addison Connor, A.B., in the Public Works Department, New York.

Frank L. Fuller, Engineer, Marblehead Water Works.

Henry M. Howe, A.M., Mining Engineer and Lecturer on Metallurgy, Massachusetts Institute Technology.

G. Russell Lincoln, Chemist, Pottstown Iron Co.

William A. Pike, Professor of Engineering and Director of the College of Mechanic Arts of the University of Minnesota.

George H. Pratt, Chemist, with Merrimac Chemical Co., South Wilmington, Mass.

Isaiah S. P. Weeks, Chief Engineer, Burlington & Missouri Railroad in Nebraska.

C. Frank Allen, Assistant Professor of Railroad Engineering, Massachusetts Institute of Technology.

Frederic A. Emmerton, Superintendent Blast Furnaces, Joliet Steel Co.

Chas. S. Minot, S. D. (Harvard), Assistant Professor of Histology and Embryology, Harvard Medical School.

Maurice B. Patch, Superintendent of Calumet & Hecla Smelting Co.

Walter Shepard, A.B., Assistant Engineer, Boston & Albany Railroad.

Richard H. Soule, A.B., General Manager, N. Y., L. E. & W. R. R. Co.

Amory Austin, A.B., Analytic and Sanitary Chemist, Boston.

George W. Blodgett, Assistant Engineer, B. & A.R.R., and Manufacturing Electrician, Boston.

Samuel M. Felton, Jr., First Vice-President of N. Y., L. E. & W. R. R. Co.

W. Dale Harris, Chief Engineer, P. P. J. Railway, Consulting Engineer M. & W. Railway, Chief Engineer O. & G. Valley Railway.

Frank B. Morse, Superintendent, Willard Mining Company.

Henry A. Phillips, Superintendent, Worcester Division, Fitchburg R. R.

Ellen H. Richards, A. M., Instructor in Sanitary Chemistry, Mass. Institute of Technology.

C. Edward Stafford, Superintendent, Bessemer and Open Hearth Departments, Juniata Iron and Steel Works.

Samuel E. Tinkham, Civil Engineer, City Engineer's Office, Boston.

Frank W. Very, Assistant Astronomer, Allegheny Observatory.

Webster Wells, Associate Professor of Mathematics, Mass. Institute of Techology.

Francis H. Williams, M. D., Physician. Assistant Professor of Materia Medica and Therapeutics, Harvard Medical School.

George H. Barrus, Expert and Consulting Steam Engineer, Boston.

William T. Blunt, Principal Inspector, U. S. Engineer's Office, Cleveland.

Joseph S. Emerson, Field Assistant, Government Survey, Sandwich Islands.

Eliot Holbrook, General Superintendent, P. & L. E. R. R.

Herbert B. Perkins, Professor of Mathematics and Astronomy, Lawrence University.

Francis H. Silsbee, Superintendent Cotton Department, Pacific Mills.

Henry K. Burrison, Instructor in Drawing in the Mass. Institute of Technology.

Frank S. Dodge, Civil Engineer and Surveyor, Government Survey, Sandwich Islands.

Edgar S. Dorr, Assistant Engineer, Sewer Department, Boston.

Charles W. Goodale, Mine Superintendent, Colorado Smelting and Mining Company.

Edward A. Handy, Engineer, Northern Division, Mexican National Railway.

Thomas Hibbard, Head Draughtsman, Deane Steam Pump Company.

L. P. Kinnicutt, S. D. (Harv.), Professor of Applied Chemistry at Worcester Polytechnic Institute.

Wilfred Lewis, Assist. Engineer, with William Sellers & Co., Philadelphia, incorporated.

Benjamin A. Oxnard, Superintendent of Fulton Sugar Refinery.

Francis T. Sargent, President of Poultney Slate Works.

Welland F. Sargent, in charge of Civil Engineering Department, Pullman Palace Car Co.

William H. Shockley, Superintendent, Mount Diablo Mill and Mining Company.

James B. Stanwood, Engineer, with Arctic Ice Machine Manufacturing Company.

William P. Atwood, Chemist at the Hamilton Print Works.

Harry T. Buttolph, Assistant City Engineer, Buffalo, in charge of Paving.

Frederick K. Copeland, Vice-President and Treasurer, Diamond Prospecting Company.

William O. Crosby, Assistant Professor of Mineralogy and Lithology, Mass. Institute of Technology.

John R. Freeman, Inspector and Hydraulic Engineer, Associated Factory Mutual Insurance Cos.

Frank W. Hodgdon, Assistant Engineer with the Harbor and Land Commissioners of Massachusetts, Boston.

Sumner Hollingsworth, President, Hollingsworth & Whitney Paper Company.

Silas W. Holman, Associate Professor of Physics, Massachusetts Institute of Technology.

Alfred E. Hunt, of the firm of Hunt & Clapp, Chemists and Metallurgical Engineers, Pittsburg Testing Laboratory.

William W. Jacques, Electrician of the American Bell Telephone Co., and Instructor Massachusetts Institute of Technology.

Samuel James, jr., Metallurgist, Pasadena Reduction Company.

Alfred C. Kilham, employed in Motive Power Department, St. Louis & San Francisco R. R.

Theodore J. Lewis, with the Standard Steel Works, 220 South Fourth Street.

Charles T. Main, Superintendent, Lower Pacific Mills.

Arthur L. Mills, Principal Assistant Engineer, Maintenance of Way and Construction Department, T., St. L. & K. C. R. R.

Charles F. Prichard, Superintendent of the Lynn Gas Light Company.
Henry H. Carter, Chief Engineer, Boston Sewer Department.
Linus Faunce, Assistant Professor of Drawing, Massachusetts Institute of Technology.
Martin Gay, Assistant Engineer, Department of Public Works of New York City.
Joseph P. Gray, Assistant Engineer in office of Proprietors of Locks and Canals on Merrimac River.
Edmund Grover, Assistant Engineer, C., B. & Q. R. R.
Richard A. Hale, Principal Assistant Engineer with the Essex Water Power Co.
John E. Hardman, Mining Engineer; Manager, Oldham Gold Co., Oldham, N. S.
Walter Jenney, Superintendent, Petroleum Refinery, Jenny Manufacturing Co.
George W. Kittredge, Engineer, Maintenance of Way, J., M. & I. R. R., and Engineer, Louisville Bridge Co.
Cecil H. Peabody, Assistant Professor of Steam Engineering, Massachusetts Institute of Technology.
George F. Swain, Professor of Civil Engineering, Massachusetts Institute of Technology.
Frank E. Wiggin, Engineer, *Ferro Carril de Sta Fé a las Colonias.*
Frederick W. Wood, Superintendent, Pennsylvania Steel Company.
Frank H. Morgan, Instructor in Chemistry, Cornell University.
Everell J. Nichols, Engineer Corps, Chicago, Burlington & Quincy Railroad.
James W. Rollins, jr., Chief Engineer, Atlantic & Danville Railroad.
Peter Schwamb, Assistant Professor of Mechanism, Massachusetts Institute of Technology.
Raphael M. Hosea, Mine Superintendent, Whitebreast Coal and Mining Co.
William W. Macfarlane, Assistant Superintendent, Quaker City Dye Works.
George H. Barton, Instructor in Determinative Mineralogy, Massachusetts Institute of Technology.
Edwin E. Chase, United States Deputy Surveyor and Mining Engineer.
Frederick W. Clark, Assistant Professor of Mining and Metallurgy, Massachusetts Institute of Technology.
Ira Abbott, Vice-President and Assistant Engineer, Dominion Bridge Company.
John H. Allen, Assistant Metallurgist, Kansas City Smelting and Refining Co.
Frank E. Came, Assistant Engineer, Dominion Bridge Co.
Harry H. Cutler, Superintendent, Newton Electric Light and Power Co.
F. Graef Darlington, Superintendent and Secretary, Cincinnati & Muskingum Valley Railway Co.
William B. Lindsay, A.B., Professor of Chemistry, Dickinson College.
James Lund, Superintendent, Indigo Works, Cochrane Chemical Co.
Evelyn W. Ordway, Professor of Chemistry and Physics, Newcomb College, Tulane University.
Theodore Parker, Assistant Engineer, C., B. & Q. R. R.
Nathaniel W. Shed, Chemist, with the Nashua Iron and Steel Co.
William R. Snead, Superintendent, The Snead Co. Iron Works.
Edward R. Warren, United States Deputy Mineral Surveyor.
George Faunce, A.B., Assistant Superintendent of Pennsylvania Lead Co.'s Works.
George H. Bryant, Professor of Mechanic Arts, Alabama Polytechnic Institute.
Harvey S. Chase, Superintendent, Gas Light Co., and Great Falls Manufacturing Co.'s Water Works.
Horace B. Gale, Professor of Dynamic Engineering, Washington University.
Charles H. Tompkins, Jr., Assistant Engineer, Idaho Mining and Irrigation Co.
T. Harris Bartlett, Assistant Engineer, Northern Pacific R. R.
Fred. M. Haines, Assistant Engineer, Northern Pacific R. R.
Francis C. Williams, Jr., Draughtsman, Burlington and Missouri River Railroad.
Charles R. Allen, Teacher of Science in New Bedford High School.
David Baker, Superintendent, Blast Furnace Department., Pennsylvania Steel Co.
Marcella I. O'Grady, Science Teacher in Bryn Mawr School.

Otis T. Stantial, Chemist, North Chicago Rolling Mill Company.

Charles L. Burlingham, Superintendent's Assistant, Chicago and Aurora Smelting and Refining Company.

Wm. H. Chadbourn, Jr., Chief Engineer and Superintendent, Construction, Wilmington, Chadbourn & Conway Railroad.

Orrin S. Doolittle, Assistant in Laboratory of the Pennsylvania Railroad.

James C. Duff, Chemist, C., M. & St. P. Railway.

Fred. E. Foss, A.B., Resident Engineer, Minn. & North-western Railroad Tunnel.

Walter R. Ingalls, Mining Engineer, Leadville, Colo.

L. Kimball Russell, Assistant Chemist, North Chicago Rolling Mill Company.

William E. Shepard, Assistant Electrician, with the Schuyler Electric Light Co.

Elwood J. Wilson, Chemist, Germania Lead Works.

George A. Armington, Instructor in Mechanical Engineering, Case School of Applied Science, Cleveland.

William D. Livermore, Second Hand in Dyehouse of Silver Springs Bleaching and Dyeing Company.

Samuel P. Mulliken, Assistant in Chemistry, University of Cincinnati.

George L. Norris, Assistant Chemist, North Chicago Rolling Mill Company.

Herbert A. Richardson, Water Analyst Mass., State Board of Health.

Herbert A. Wilcox, Assistant in Laboratory of Joliet Steel Company.

Total number of students 502

ONTARIO SCHOOL OF PRACTICAL SCIENCE.

For purposes of comparison the course of study and certain other information respecting the Ontario School of Practical Science is submitted herewith :

Faculty :

Sir Daniel Wilson, Knt., LL.D., F.R.S.E., Professor of Ethnology.
E. J. Chapman, Ph.D., LL.D., Professor of Mineralogy and Geology.
James Loudon, M.A., Professor of Physics.
R. Ramsay Wright, M.A., B.Sc., Professor of Biology.
J. Galbraith, M.A., Assoc. M. Inst. C.E., Professor of Engineering.
W. H. Pike, M.A., Ph.D., Professor of Chemistry.
W. H. Ellis, M.A., M.B., Professor of Applied Chemistry.
A. Baker, M.A., Professor of Mathematics.

Assistant Instructors :

W. J. Loudon, B.A., Demonstrator in Physics.
F. W. Babington, Demonstrator in Applied Chemistry.
A. B. McCallum, B.A., Lecturer in Physiology.
J. H. McGeary, B.A., Fellow in Mathematics.
A. C. McKay, B.A., Fellow in Physics.
J. J. McKenzie, B.A., Fellow in Biology.
G. Chambers, B.A., Fellow in Chemistry.
F. G. Wait, B.A., Fellow in Mineralogy and Geology.
D. Burns, Fellow in Engineering.

Origin of the School.

The Act for the establishment of the School of Practical Science was passed in 1873. After a fruitless attempt to secure the attendance of students as an independent institution doing elementary work, the school was removed to the immediate vicinity of the Provincial University in order that its students might avail themselves of the instruction of the professors of University College. This change was made in 1877.

The position which it is intended that the School of Practical Science shall occupy in the educational system of Ontario may be indicated as follows :—

I.—Students, who have passed through the regular courses of the School, will be enabled to prosecute professionally : (1) Engineering ; (2) Assaying and Mining Geology ; or (3) Analytical and Applied Chemistry.

The instruction in Engineering is designed to give the student a thorough knowledge of the scientific principles of the Profession, and also to afford such practical training in drawing and surveying as will make him immediately useful in the office and field.

The establishment of a Diploma for special qualifications in Assaying and Mining Geology, apart from the knowledge of these subjects incidental to the course of Mining Engineering, is called for by the necessity which exists for the development of the mineral wealth of the Province. Students who pass through the course necessary to obtain this Diploma will have acquired the knowledge requisite for inspecting and surveying mineral lands, as well as the ability to report accurately on the composition and value of economic minerals generally.

The importance of the study of Chemistry is now fully recognized, and in Canada, through the Public Analysts and otherwise, protection is being secured to consumers, while the producers are necessarily brought to recognize its importance. The course in Chemistry is such as to fit the student for the position of Public Analyst or of Consulting or Resident Chemist.

II.—It is designed to furnish preliminary scientific training for students entering the professions of Surveying and Medicine.

Certificates in Surveying will be granted after due examination, which will have the effect of shortening the ordinary period of apprenticeship to a Land Surveyor, by the length of time covered by such certificates—one, two or three Sessions, as the case may be.

The School of Practical Science offers to Medical Students thoroughly practical courses of instruction in those sciences which form the best preliminary training for the study of Medicine. The Lectures and Laboratory Courses are arranged so as to conform with the Regulations of the University of Toronto.

III.—Persons desirous of instruction in any of the subjects taught in the School may be allowed to attend separate courses in these as *Special Students.*

Mechanical Engineering.

Students intending to become Mechanical Engineers will enter as special students, and receive instruction in the principles of mechanism, the theory of machines and drawing, together with such work in the civil engineering course as may be suitable for their purpose.

Electrical Engineering.

Students intending to become Electrical Engineers are admitted as special students, and will receive instruction in drawing, mechanical engineering and electricity. The Physical Laboratory is furnished with a good collection of electrical instruments ; and a separate room will be set apart for experimental work in this department. Special attention will be given to the subject of Electrical Testing. In connection with the Physical Laboratory there is a workshop, the power being given by a 4 h.-p. gas engine.

Architecture.

Students who intend to pursue Architecture as a profession are advised to take, if possible, the regular course in Civil Engineering, as the instruction given in this course in the subjects of Drawing, Coloring, Principles of Construction (Carpentry, Masonry and Ironwork), Strength and other Properties of Building Materials, Flow of Water and Air, Theory of Heat, etc., will be as useful to them as to civil engineers.

Regulations Respecting the School of Practical Science.

1. The internal management and discipline of the School shall be vested in the Board consisting of the Professors and the Chairman, as nominated by the Lieutenant-Governor in Council.

2. The Academic Year shall consist of two Terms, the First Term extending from 1st October to 23rd December; and the Second Term from 8th January to 18th April.

3. There shall be three Departments in which Diplomas shall be granted viz.:—

(1) Civil Engineering (including Mining Engineering).
(2) Assaying and Mining Geology.
(3) Analytical and Applied Chemistry.

A Diploma shall be granted to each student who shall have completed to the satisfaction of the Faculty, the Regular Course in any of the above Departments.

4. The Regular Course for the Diploma of the School in each Department is three years in duration.

5. A student who proposes to obtain the Diploma of the School in one of the above Departments must have passed the Matriculation Examination required for admission to a University in any part of Her Majesty's Dominions, or the Entrance Examination of the Law Society of Upper Canada, or of the College of Physicians and Surgeons, or any of the Examinations prescribed for Teachers in Public or High Schools of the Province of Ontario, or must present a certificate signed by a Head Master of a High School or Collegiate Institute that he possesses qualifications equivalent to those required for such teachers.

6. Special Students may be permitted to attend such lectures or courses of instruction or of practical work as the Board may think proper.

7. Certificates of attendance and standing may be given upon due examination to Special Students, and such students shall not be required to pass an Entrance Examination.

(6 and 7 apply to Medical Students taking special work, also students preparing themselves to be Surveyors, Mechanical or Electrical Engineers, Architects, etc.)

8. At the conclusion of each term examinations will be held in the different subjects taught, and prizes will be awarded for excellence in each Department at the end of the session. Candidates for Diplomas and Certificates are required to enter for these.

9. All Regular Students are required to be in attendance at the School during the whole of each term, unless exempted by special permission of the Board. The term will not be allowed to any student who has attended less than three-fourths of the required lectures and practical lessons, or who has been reported to the Board for bad conduct, and adjudged guilty thereof.

10. Students of the School of Practical Science shall attend such courses of lectures as are delivered by the Professors of the University College to the students thereof, so far as applicable to both classes of students, while instruction of a practical character in the Department of Engineering is especially appointed for students of the School.

Note.—The fees chargeable are:—For first session, $30; for second, $40; for third, $50.

I. Department of Engineering.

This Department is intended to afford the necessary preliminary preparation to students intending to become Civil Engineers (including under this term Mining Engineers.)

Students who wish to devote themselves to the practice of Mining Engineering are allowed to take the work specially mentioned under this head, in the Third Year, and to omit the work in Experimental Physics.

They are advised, however, to take, if possible, the regular course in Civil Engineering and the special work subsequently as Special Students.

The Degree of C. E. is granted by the University of Toronto to such students as pass the prescribed examination in Engineering.

Subjects of the First Year.

Pure Mathematics.—Euclid, Algebra, Plane Trigonometry, Analytical Geometry of two dimensions.

Applied Mathematics.—Statics and Dynamics (with special reference to Structures and Machines).

Drawing.—Copying from the Flat. Lettering. Model Drawing. Map and Topographical Drawing. Orthographic (including Isometric), and Oblique Projections. Graphics.

Surveying.—Field and Office Work—Chain and Compass Surveys—Topography—Preliminary Instruction in use of the Transit and Theodolite—Plotting, Mensuration.

Chemistry.—General Chemistry. Practical Chemistry.

Subjects of the Second Year.

Pure Mathematics.—Differential and Integral Calculus. Spherical Trigonometry.

Applied Mathematics.—Hydrostatics. Geometrical Optics. Plane Astronomy.

Experimental Physics.—Light: Use of the Heliostat and Spectroscope. Experiments with Lenses and Mirrors. Theory of the Telescope and Microscope, and Reflecting instruments.

Drawing.—Subjects of First Year continued. Coloring and Shading. Descriptive Geometry, including Projections of the Sphere and Theory of Mapping. Machines and Structures.

Engineering and Surveying.—Theodolite Surveying (including laying out Railway Curves). Principles of Geodesy (considering the Earth a Sphere). Applied Mechanics. Theory of Strength of Materials. Materials of Construction. Methods and Processes. Theory of the Theodolite, Transit-Theodolite and Level,

Chemistry.—Practical Chemistry.

Chemistry (Applied).—Combustion, Fuel, and Furnaces. Artificial Lighting. Explosives. Laboratory Practice.

Mineralogy and Geology.—Elements of these Sciences. Blowpipe Practice. Determination of Minerals.

Subjects of the Third Year.

Applied Mathematics.—Dynamics of Machines. Thermodynamics and Theory of the Steam Engine. Hydraulics.

Experimental Physics—Heat: Use of the Cathetometer, Dividing Engine, and Spherometer, Thermometry and Calorimetry. Principle of Least Squares.

Drawing.—Subjects of previous years continued. Shades and Shadows, Stone Cutting, Perspective. Original Designs (Bridges, Roofs, Floors, etc.)

Engineering and Surveying.—Subjects of previous years continued. Levelling. Setting out Excavation, Cross sectioning, Calculation of Quantities. Application of principles to practical problems connected with the design and construction of various Structures and Machines, *e.g.*, Foundations, Retaining Walls, Arches, Roofs, Bridges, Roads, Railways, Canals, Sewers, Water Wheels, Steam Engines, Hydraulic Machinery, Mining Machinery, etc. Practical Astronomy. Geodesy (considering the Earth a Spheroid).

Chemistry (Applied).—Mortars and Cements. Bricks and Artificial Stones. Preservation of Wood, Iron and Stone. Water, Air and Sewage. Metallurgy of Iron and Steel. *Metallurgy of Copper, Lead, Silver and Gold.

Mineralogy and Geology.—Economic Minerals of Ontario. Blowpipe Analysis and Determinative Mineralogy. Assaying and Mining Geology, Mining Calculations. Crystallography and Palæontology.

Dominion and Provincial Land Surveyors.

Courses of instruction will be given in accordance with the requirements of the Statutes relating to the Dominion and Provincial Land Surveyors, which will enable the students, who, after examination obtain certificates therein and who have otherwise fulfilled the provisions of the said Statutes, to present themselves for final examination before the proper Boards, at an earlier period in their apprenticeship than would otherwise be permitted.

Extracts from the Provincial Act Respecting Land Surveyors and the Survey of Lands.

12.—(2) Any person who has followed a regular course of study at the Ontario School of Practical Science in the subjects of drawing, surveying and levelling, and geodesy and practical astronomy, and who has thereupon received, after due examination, a certificate of having passed one session, two sessions, or three sessions, as the case may be, in the study of the aforesaid subjects, may, after having passed the preliminary examination hereinbefore required for admission to apprenticeship with a land surveyor, be received as an apprentice by any practising land surveyor, and shall thereupon, if he has received a certificate of having passed three sessions in the study of the said subjects, be only holden to serve as such apprentice during twelve successive months of actual service; or, in case he has only received a certificate of having passed only one or two sessions, as the case may be, in the study of the said subjects, then, for such time of actual service as, with the period spent by him at such session or sessions, suffices to make up the full term of three years.

(3) After such actual service, such person shall, subject to the other provisions of this Act, have the same right to present himself for and to undergo the examination required by law, and if found qualified, then to be admitted to practice as a land surveyor, as if he had served the full three years' apprenticeship otherwise required by law.

14. The privilege of a shortened term of apprenticeship shall also be accorded to any graduate of the Military College at Kingston and of the Ontario School of Practical Science, and such person shall not be required to pass the preliminary examination hereinbefore required for admission to apprenticeship with a land surveyor, but shall only be bounden to serve under articles with a practising land surveyor duly filed as required by section 17 of this Act, during twelve successive months of actual practice, after which, on complying with all the other requirements, he may undergo the examination by this Act prescribed.

Extract from the Dominion Lands Act.

Every graduate in surveying of the Royal Military College of Canada, and every person who has followed a regular course of study in all the branches of education required by this Act for admission as a Dominion Land Surveyor, through the regular sessions, for at least two years in any College or University where a complete course of

*Mining Engineering only.

theoretical and practical instruction in surveying is organized, and who has thereupon rceived from such College or University a Diploma as Civil Engineer, shall be exempt from serving three years as aforesaid, and shall be entitled to examination after one year's service under articles with a Dominion Land Surveyor, at least six months of which service has been in the field, on producing the affidavit required by the next preceding clause as to such service; but it shall rest with the Board to decide whether the course of instruction in such College or University is that required by this clause.

2.—Department of Assaying and Mining Geology.

In this Department the student is fully prepared in all the methods of analysis necessary to render him a competent Assayer. He is also qualified to survey and report upon the value of mineral lands.

Subjects of First Year.

1. Elementary Mathematics, including Mensuration and Plane Trigonometry.
2. Elements of Natural Philosophy, including Mechanics and Hydraulics.
3. Inorganic Chemistry.
4. Elementary Mineralogy and Blowpipe Practice.
5. Elementary Biology.
6. Physical Geography, Palæontology and Geology.
7. Drawing.

Subjects of Second Year.

1. Higher Mathematics, including Spherical Trigonometry, etc.
2. Chemistry, with Laboratory practice in Qualitative Analysis.
3. Blowpipe Analysis and Determinative Mineralogy.
4. Geology and Economic Minerals of Canada.
5. Surveying and Levelling.

Subjects of Third Year.

1. Quantitative Chemical Analysis.
2. Metallurgy.
3. Assaying.
4. Study of Metallic Veins and other Mineral Deposits, Mining Calculations, Examinations of Mineral Lands.

3.—Department of Analytical and Applied Chemistry.

This Department is under the charge of the Professor of Applied Chemistry.

The course is intended to render the student proficient in all the methods of Analytical Chemistry, and to fit him for such positions as that of Public Analyst, Consulting Chemist in regard to Manufactures, or Resident Chemist in manufactories where such is required.

Subjects of First Year.

1. Algebra, Euclid and Plane Trigonometry.
2. Natural Philosophy, with work in Laboratory.
3. Elementary Biology.
4. Inorganic Chemistry, Elementary and Advanced, with work in the Laboratory.

Subjects of Second Year.

1. Elementary Mineralogy and Geology.
2. Blowpipe Practice and Assaying.
3. Organic Chemistry with Applied Chemistry, Laboratory Work in Qualitative and Quantitative Analysis.

Subjects of Third Year.

Candidates are expected to be able to read Chemical Works in the French and German languages.

1. Applied Chemistry.

2. Inorganic Chemistry, including Thermo-Chemistry and the study of Mendelejeff's Periodic Law. Advanced Organic Chemistry, Historical Development of Chemical Theory and Physiological Chemistry.

3. Laboratory Works, including Technical Analysis, Quantitative Mineral Analysis, a prescribed course in Physiological Chemistry, and in Chemistry in its relations to Hygiene and Forensic Medicine.

Synopsis of the Courses of Lectures and Practical Instruction Given in Each Department.

I. Engineering.

☞Text-books for the First Year marked (*a*); for Second Year, (*b*); for Third Year, (*c*).

(I.) Drawing.

Model Drawing, Machines and Structures, Map and Topographical Drawing, Designs and Estimates, Graphical Calculations.

Descriptive Geometry, including Practical Geometry (Plane and Solid); Orthographic, Oblique and Perspective Projections; Intersections of Surfaces, Shades and Shadows, Stone Cutting, Principles of Mechanism, Theory of Mapping, etc.

Text Books and Books of Reference.—Davidson's Projections. Angel's Plane and Solid Geometry, Binns' Orthographic Projection. Church's Descriptive Geometry (*a*), (*b*), (*c*). Warren's Stone Cutting (*c*). McCord's Lessons in Mechanical Drawing. Worthen's Topographical Drawing (*a*), (*b*), (*c*).

Fee for Special Students, $10.

(II.) Surveying and Levelling.

Land Surveying—Chain Surveys. Compass and Theodolite Surveys. Methods of Keeping Field Notes. Determination of Heights and Distances. Plotting.

Levelling—Longitudinal and Cross Sections. Plotting.

Setting Out—Setting out Straight Lines and Curves. Setting out Levels.

Mensuration—Lines, Surfaces and Solids. Timber, Masonry, Iron and Earthwork. Capacities of Reservoirs, etc.

Lectures will also be given on the distinctive features of Mining and Hydrographic Surveying.

Text Books.—Murray's Manual of Land Surveying (*a*). Gillespie's Higher Surveying (*b*), (*c*). Henck's or Trautwine's Railway Curves (*b*).

Fee for Special Students, $10.

(III.) Geodesy and Practical Astronomy.

Geodesy—Field Work. Computation of the Triangles (considering the Earth, 1st as a Sphere; 2nd, a Spheroid). Determination of the Figure of the Earth.

Practical Astronomy.—Methods of determining Latitude, Local Time, Direction of the Meridian, and Difference of Longitude. Theory of the Theodolite, Transit-Theodolite, Level, Sextant, and Solar Compass.

Text Books.—Gillespie's Higher Surveying (*b*), (*c*). Chauvenet's Spherical and Practical Astronomy (*c*). Nautical Almanac for 1889 (*c*). Chambers' Practical Mathematics (*c*).

Fee for Special Students, $15.

(*IV.*) *Applied Mechanics.*

Statics.—The Calculation of the Stresses in Framed Structures, Solid and Riveted Beams, Stone Arches, etc. Both Graphical and Analytical Methods used.

Theory of the Strength of Materials.—Designing of Structures in Timber, Iron and Masonry—Arches, Retaining Walls, Foundations, Roofs, Bridges, etc.

Dynamics.—Representation and Measurement of Forces and Motions. Principles of *Work* and *Energy.* Efficiency of Machines. Friction. Transmission of Energy—Belts, Shafts, Crank and Connecting Rod, etc. Fly-Wheels, Governors. Balancing of Machinery, etc., etc.

Strength of the Parts of Machines.

Machine Design.

Hydraulics.—Discharge of Water through Orifices, Notches, etc. Flow in Pipes and Open Channels. Water Power. Water Wheels, Turbines, Pumps, etc.

Thero-Dynamics and Theory of the Steam Engine.

Text Books and Books of Reference.—Von Ott—Graphic Statics (*a*). DuBois—Graphical Statics. DuBois—Strains in Framed Structures. Wood—Resistance of Materials. Wood—Bridges and Roofs. Rankine—Applied Mechanics (*b*), (*c*). Rankine—Steam Engine and other Prime Movers. Unwin—Elements of Machine Design. Shann—Elementary Treatise on Heat (*c*). Kennedy—Mechanics of Machinery. Jackson—Hydraulic Manual (*c*). Neville—Hydraulic Tables and Formulæ (*c*).

Fee for Special Students, $15.

(*V.*) *Principles of Mechanism.*

Principles of the Transmission of Motion without reference to Force:—Pitch surfaces, Spur Wheels, Bevel Wheels, Skew-bevel Wheels, Trains of Wheelwork, Teeth of Wheels, Cams, Cranks, Eccentrics, Links, Bands and Pulleys, Hydraulic Connections, Frictional Gearing, Link Motion for Slide Valves, etc., etc.

Text Books and Books of Reference.—Rankine—Machinery and Millwork. Camus—Teeth of Wheels. MacCord—Slide Valve and Eccentric. Goodeve—Elements of Mechanism.

Fee for Special Students, $15.

The foregoing comprises the work to which the lectures and practical instruction will be principally confined. In addition, the Student will be required to obtain, by reading and observation during his course, a certain amount of information regarding the processes and details of Engineering Works, as below:—

(*VI.*) *Engineering Works.*

Roads and Bridges.
Canals and Harbors.
Water and Sewage Works.
Manufacture of Iron and Steel.
Manufacture of Mortars and Cements.
Workshop and Foundry Practice.
Mining Machinery and Processes.

Since information on these subjects is given in a plain and intelligible manner in the various treaties relating thereto, which can always be consulted by the Engineer when engaged in the actual practice of his profession, it has not been deemed expedient that much time should be given to them in the School.

(*VII.*) *Mathematics.*

The Pure Mathematics included in this course will be taught in University College.

The Applied Mathematics will be taught partly in University College and partly in the School.

(*VIII.*) *Vacation Work.*

Thesis and Construction Notes.

A subject will be given at the end of each session on which the student will be required to write a Thesis (accompanied with drawings and specifications when necessary), during the subsequent vacation.

The student will also be required to make, during the vacation, full and clear notes of various constructions of engineering interest that may fall under his notice.

The value of both the Thesis and the construction notes will be taken into account in determining his standing at the next following examination.

Subject of Thesis for Second Year.—Roads, Streets and Pavements.
" " *Third* " Sanitary Drainage.

Books of Reference.—Gillmore—Roads, Streets and Pavements. Waring—Sanitary Drainage of Houses and Towns. Latham—Sanitary Engineering.

Any other works on the above subjects may be consulted, and results of original observation should be given.

II. Chemistry.

All the instruction in this subject is given in the School of Practical Science.

Courses of Lectures.

I. Inorganic Chemistry.—A course on Elementary Inorganic Chemistry suited to the Pass Examination, University of Toronto; to the Medical Examination, First Year, University of Toronto; and to the First Year, Engineering Course, School of Practical Science.

A Course on the Application of Chemical Theory to Calculation for the First Year, Engineering Course.

A Course on Advanced Inorganic Chemistry for the Second Year, Honor Science Examination, University of Toronto.

A Course on the Theory of Qualitative Analysis for the Second Year, Honor Science Examination, University of Toronto.

II. Organic Chemistry.—A Course on Organic Chemistry for the Third Year, Honor Science Examination, University of Toronto.

A Course on Elementary Organic Chemistry, for the Medical Examination, Second Year, University of Toronto.

III. Historical Development of Chemical Theory.—A Course for the Fourth Year Examination in Science, University of Toronto.

IV. Physiological Chemistry.—A Course for the Fourth Year Examination in Science, University of Toronto.

V. Applied Chemistry.—A Course on the Chemistry of Combustion, Fuel, Furnace, Artificial Lighting and Explosives, suited to the Examination for Second Year, Engineering Course.

A Course on the Chemistry of Building Materials, Water, Air and Sewage, and on Metallurgy, suited to the Examination for Third Year, Engineering Course.

Practical Work in the Laboratory.

I. Courses including Qualitative Analysis, suited to the Examinations for (*a*) First Year, Engineering Course; (*b*) Second Year, Honor Science, University of Toronto; (*c*) First Year, Medicine, University of Toronto.

II. Courses including Quantitative and Qualitative Analysis, for (*a*) Second Year, Engineering Course; (*b*) Third Year, Honor Science, University of Toronto.

III. Physiological Chemistry for Second Year Examination in Medicine, University of Toronto.

IV. Forensic and Hygienic Chemistry for Third Year Examination in Medicine, University of Toronto.

V. A Course for Fourth Year Examination in Science, University of Toronto.

III. Mineralogy and Geology.

Courses of Lectures.

1. Elementary Course.—Rudiments of Mineralogy. Geology and Palæontology. Physical Geography.

Text Books and Books of Reference.—Chapman's Mineralogy and Geology of Canada, 3rd edition. Dana's Manual of Mineralogy. Dana's Text Book of Geology. Page's Physical Geography. Johnston's Elementary Physical Atlas.

2. Advanced Course.—Mineralogy and Crystallography. Geology and Palæontology. Mathematics of Crystallography. Physical Geography. Geology and Palæontology of Canada.

Text Books and Books of Reference.—Dana's System of Mineralogy. Chapman's Outline of the Geology of Canada, 1876. Nicholson's Palæontology. Chapman's Synopsis.

Practical Courses.

1. Use of Blowpipe—Chapman's Blowpipe Practice.
Fee, $10.

2. Blowpipe Analysis, Determinative Mineralogy. Economic Minerals of Canada.
Keral's Leitfaden bei qual. u. quant. Lothrohr-Untersuchungen, etc. Aufl. 2. Plattner's Blowpipe Treatise. Von Kobell's Tafeln. Chapman's Mineral Tables.
Fee, $15.

3. Assaying.—Mitchell's Assaying, by Crooks. Kerl's Probirkunst. Chapman's Assay Notes.
Fee, $50.

4. Mining Geology.—*Books of Reference*—Burat's Géologie Appliquée and Cours d'Exploitation des Mines. Niederist's Bergbaukunde. Von Cotta's Erzlagerstatten.
Fee, $20.

IV. Biology.

Those students of the School of Practical Science who are required to take Biology as part of their course join the Art Classes of the University of Toronto.

The following arrangements will be in force during the year 1888-9:

1. A course of Elementary Lectures on Biology will be given on Wednesdays and Fridays at 12 noon to prepare Candidates for the University Examination of the First Year.

2. A course of more advanced Lectures on Animal Physiology for Honor Students of the Second Year will be given three times a week at an hour to be arranged.

Text Book.—Yeo's Manual of Physiology.

3. Candidates for the Second Year Honor Examination in addition to attending the above Lectures will study Thomé's Lehrbuch der Zoologie as an introduction to the Zoology of the Vertebrata.

4. The Practical Course for Honor Students of the Second Year will be devoted to the methods of Biological Investigation, and to the study of typical forms of plants and animals, such as are treated of in Huxley and Martin's Elementary Practical Biology, new edition. Necessary Works of Reference will be found in the Laboratory. There will also be opportunities for the study of the Canadian Vertebrate Fauna (Text-book, Jordan's American Vertebrates), and for a revision of the Canadian Flowering Plants, but the student is expected to have familiarized himself with the Canadian Flora during the preceding long vacation.

For Reference—Spotton's Canadian Flora or Gray's Manual.

5. Honor Students of the Third Year will study Cryptogamic Botany and Vegetable Physiology twice a week during the Michaelmas Term, and during the Easter Term the Zoology of the Invertebrata.

Books of Reference.—1. Goebel's Outlines of the Classification of Plants. 2. Vines's Lectures on the Physiology of Plants. 3. Claus's Zoology, translated by Sedgwick.

6. The Practical Course for Third Year Students will be devoted to the study of typical forms of Cryptogamic Plants and Invertebrate Animals. In addition to the text books referred to above Brooks's Invertebrate Zoology will be required.

7. Weidersheim-Parker's Elements of Comparative Anatomy of the Vertebrata, and Foster's Physiology, last English edition, are recommended for Honor Students of the Fourth Year, and the following works will be required in the Practical Course:

1. Klein's Elements of Histology.
2. Parker's Zootomy.
3. Foster and Balfour's Embryology.
4. Charles' Physiological Chemistry.

Works of reference on Bacteriology and the other subjects specified in the University Curriculum will be found in the Laboratory.

8. Students of all years are required to provide themselves with dissecting instruments, slides, cover-glasses, etc., and to pay a Laboratory fee for the use of microscopes and material for study.

V. Mathematics and Physics.

The Ordinary Course embraces Euclid, Algebra, Plane Trigonometry, Statics of Solids and Fluids, Dynamics of a Particle, Geometrical Optics, Sound, Heat, Electricity, and Plane Astronomy.

The Lectures in Physics will be fully illustrated by experiments.

The Advanced Course embraces Spherical Trigonometry, Analytical Geometry (Plane and Solid), Differential and Integral Calculus, Theory of Equations, Statics of Solids and Fluids, Particle and Rigid Dynamics, Hydrodynamics, Optics, Acoustics, Thermodynamics, Electricity, and Astronomy.

VI. Ethnology.

Anthropology. The Skull, its bones and sutures. Structure and functions of the brain. Typical race-forms of head. Hair, color and other distinctive ethnical elements. Succession of races. The Prehistoric, Unhistoric, and Historic races.

Physical evidences of diversity of race.

Philological evidence.

The Lectures are illustrated by means of maps, drawings, specimens of typical skulls, primitive implements, etc.

Text Books.—Tylor's Anthropology: an introduction to the study of Man and Civilization. Brace's Manual of Ethnology. Latham's Ethnology of British Isles. Latham's

Ethnology of Europe. Latham's Man and his Migrations. Max Müller's Science of Language, 1st Series.

Additional Books of Reference.—Pritchard's Researches into the Physical History of Man. Pritchard's Eastern Origin of the Celtic Language (Latham's Ed.) Latham's Varieties of Man. Neibuhr's Ethnography. Wilson's Prehistoric Man (3rd Ed.)

Physical Laboratory and Workshop.

The Physical Laboratory which has been lately established in connection with University College is furnished with a large collection of apparatus for lecture experiments in the Departments of Mechanics, Sound, Light, Heat and Electricity. It is also well supplied with instruments of precision for individual work in the same departments. In addition to an Elementary Laboratory, there are several special Laboratories, which offer unusual facilities for the conduct of experiments in the various branches of Physics.

The electrical apparatus include Electrometers, Galvanometers, Resistance Coils and Bridges, Testing Keys, Batteries, Electrical Machines (Holz and Carré), Ruhmkorff Coils, Crookes' Tubes, Telephones, etc., etc.

The workshop contains a gas engine, lathes and other tools.

Modern Languages.

Students in the regular courses are admitted, without extra charge, to the French and German classes in University College (see regulation 10). No special examinations are held in these languages, but it is expected that every student of a regular course should be able to acquaint himself with the contents of any of the works necessary to his profession written in these languages. Such books may be prescribed for the terminal examinations.

Libraries, Museums, Etc.

The Library, Museums and Herbarium of the University of Toronto are open to regular students.

The Graduates.

The following is a list of Graduates who hold positions for which they were qualified by their course of study at the School of Science :—

G. H. Duggan, Dominion Bridge Co., Montreal.
J. W. Tyrrell, P. and D.L.S., Canadian Pacific Railway, Maine.
D. Burns, Fellow in Engineering, School of Practical Science, Toronto.
A. R. Raymer, Assistant Engineer, Canadian Pacific Railway, Greenville, Me.
W. C. Kirkland, Canadian Pacific Railway.
J. McDougall, B.A., Welland Canal.
E. E. Henderson, Canadian Pacific Railway, Brownville, Me.
T. K. Thompson, Dominion Bridge Co., Montreal.
H. G. Tyrrell, Assistant Engineer, Canadian Pacific Railway, Maine.
A. E. Lott, Atcheson, Topeka and Santa Fe Railway, Topeka, Kan.

APPENDIX.

In order to ascertain the state of public opinion on the question of technical education, and at the same time call attention to the necessity for immediate action, the following circular was sent to the leading manufacturing engineers, architects and foremen of large factories, and working men representing the various industries of Ontario.

TORONTO, 3rd December, 1888.

DEAR SIR,—I purpose submitting to the Legislative Assembly at its next session, a scheme for establishing, in the School of Practical Science, full courses of instruction in Applied Chemistry, Applied Mechanics and Architecture.

While, in the interests of the industrial classes, it is necessary that the course of instruction should be thoroughly practical, and at the same time educational, it is also necessary that the special wants of the industries of the country should be kept in view. It occurred to me, therefore, if I only could consult those employing skilled labor of various kinds, that I should be able to provide this special training with more certainty and satisfaction to both manufacturer and artisan.

I have accordingly decided to invite a number of manufacturers, skilled mechanics and others having interests of a similar character, to meet me at the Education Department on Wednesday, the 19th instant, at 2.30 p. m., in order that I may ascertain, if possible, on what particular lines, instruction such as I have above indicated, could be made most useful.

The attention of the meeting will be mainly directed (1) To a consideration of the various kinds of skilled labor now required to carry on the industries of the country and the best means of rendering it more productive and therefore more valuable ; (2) To a consideration of what courses of instruction would be necessary to provide such skilled labor at home as is now supplied from abroad, and (3) To enquire what industries (if any) not yet established in Ontario could be made productive, provided we could supply them with skilled labor.

I shall be gratified if you can make it convenient to attend at the time above mentioned and aid with your counsel and experience.

Yours truly,

GEO. W. ROSS,
Minister of Education.

In response to the above circular a meeting was held, of which the report that follows, taken from the Toronto *Globe*, may be considered a good summary :

TECHNICAL EDUCATION ENDORSED BY EMPLOYERS AND EMPLOYÉS.

Enthusiastic Meeting of Ontario's Manufacturers and Artisans at the Education Department —Masterly Address by the Minister of Education — The True Sphere of the School of Science set forth.

The meeting of manufacturers, artisans and others, held yesterday afternoon in the Education Department in response to the invitation of Hon. G. W. Ross, Minister of Education, must have a powerful influence on the development of our national system of education on lines tending towards the recognition of skilled labor and the requi-

sites necessary to its production. The gentlemen who met Mr. Ross to assist him in coming to a proper conclusion as to the best way to reorganize the School of Practical Science in the interests of skilled labor, were throughout the meeting profoundly interested in the cause which brought them together. It is worthy of note that not a single speaker consumed one moment of time to no purpose, the addresses, as might be expected from those engaged in callings requiring skill, tact and dexterity, being in every sense of the term practical and to the point. They unanimously declared that the time has come in Ontario when technical education should be vigorously and unflinchingly supported in connection with the National University, giving as their reasons not hearsay or speculative theories, but the experiences they learned in the industrial establishments controlled by them, and by the commercial relations they are called upon to hold with foreign countries. Canadian skilled labor was not by any means depreciated, but the Minister of Education was told that it could be made more efficient by providing the future artisans of the country with institutions where they might acquire a dexterity of eye and hand and a knowledge of the chemical compounds of raw material. It was represented that the manufacturer is a daily loser by being compelled to keep in his employ men of no practical skill, while the loss to the nation and to the artisan were no less forcibly and intelligently set forth. The tone of the meeting, the extraordinary amount of information elicited, and the unanimity of the conclusions arrived at, were such as are seldom experienced at any public gathering.

Who Were Present.

Manufacturers, Artisans, Divines, etc., in Congress.

The following were present :—E. Burke architect ; W. B. Hamilton, manufacturer ; Chas. Rogers, G. B. Smith, M.P.P., Prof. Chapman, Rev. Dr. Sheraton, Sir Daniel Wilson, Rev. Dr. Wild ; Chas. Fuller, manufacturer ; Dr. Stuart, Prof. Young, John Cameron ; W. E. Redway, naval architect ; Vicar-General Rooney, Hamilton McCarthy, Thomas E. Edmondson ; E. A. Edmondson, miller, Oshawa ; William Macdonald, stonecutter ; J. Mitchell, carpenter ; Rev. Dr. Dewart ; Thomas Martin, miller, Mount Forest ; F. H. Vann, woollen manufacturer, Weston ; Dr. Oldright, Silas James, Prof. Pike, Geo. McMurrich, Prof. Shuttleworth. D. Burns, E. G. Gurney, James Smith, Wm. J. Allen, James Hedley, W. H. Elliott, Samuel Smith, John D. Nasmith, Alex. Nairn, Wm. Revell, J. M. Rose, John Baillie, William Purvis, G. T. Berthron, Wm. Folsom, Frank E. Leonard, J. Dempster, John Galt, S. S. Malcolmson, Arthur W. Holmes, John W. Davey, W. J. Burroughes, Ald. Harvie, M. Shipway, James B. Ives, D. S. Macorquodale, Principal Dickson, W. H. Rodden, Prof. Galbraith, A. M. Wickens, Prof. Alfred Baker, W. Campbell, W. R. Brock, M. B. Aylesworth, Rev. Dr. Davies, Thomas Moor, R. W. Gambier-Bonsfield, John W. Dowd, Mr. Taylor, Dr. J. E. White, Elias Rogers, O. Wilby, Weston ; E. Samuel, Alan Macdougall, Geo. Smith, W. D. Mathews, H. J. Hamilton, Dr. P. H. Bryce.

Address from the Minister of Education.

Hon. G. W. Ross stepped behind the table that was placed on the platform and opened the proceedings with a compact speech, in which he put lucidly before the meeting the objects for which they were called together. He began by saying that he felt highly honored by the very generous response to the invitation he had sent out by circular to meet him for the discussion of such measures as would lead to the improvement of the School of Practical Science and more efficient mechanical training of all kinds. He had already been considering some immediate changes in the School of Science that would very much broaden its course and increase its facilities for a thorough mechanical training. When in England he had gone carefully over the Mechanical School of South Kensington with a view to obtaining hints for the development of the Canadian school, and during a recent visit to the five or six Mechanical schools of the United States he had found that the Americans were giving a very large amount of attention to

that portion of education that would best advance the industries of their country. This was particularly interesting to us, as they are our greatest competitors and have a system very like ours. The Americans have 90 schools somewhat similar to our School of Practical Science, in which are employed 1,000 instructors, and where there attended last year 10,532 students. The effect of that large number of skilled mechanics and artisans turned out annually among the body of the people could not well be over-estimated.

These American schools are also supported to a considerable extent by the State. Forty-eight out of the ninety are endowed with land grants, and possess buildings of a total value of $5,152,455, and enjoy a joint income of $962,986. The remaining forty-two are not endowed, however; but they are working in buildings valued at $2,004,422, and receive an annual income amounting to $698,758.

The Minister continued, stating that the first object of the meeting was to find out in what department skilled labor is most urgent. It might be claimed that there was no urgency at all for skilled labor, but in reply to this he would refer to the shoals of letters he had received from practical men all over the country, which tended to the contrary. Iron workers and makers of engines had complained to him of the want of skilled labor, and wood-workers and workers in wool similarly. He had been looking at the commercial statistics to see what articles we imported that, with skilled labor, we ought to be able to manufacture. The returns show that the following articles are imported in the following quantities :—Blacking, $54,130; black lead, $25,766; blueing, $37,080; drugs and chemicals, $1,101,963; fertilisers, $6,988; gutta percha, $546,187; inks, etc., $71,943; oils, minerals, etc., $1,226,878; paints and colors, $553,549; soaps, $97,679; varnishes, $113,131. He contended that these things, through knowledge of applied chemistry, ought to be manufactured in this country.

Further, he had investigated the importations of manufactured articles, with the following results :—Brass manufactures, $404,161; earthenware, $750,691; fancy goods, $2,480,000; glass manufactures, $1,269,482; iron and steel manufactures, $9,745,957; leather, $1,967,572; paper, $1,233,591; wood, $1,149,324. A large percentage of the cost of these articles is the labor. In 1881 $30,604,000 was paid to Canadian workingmen in wages, when at the same time $157,989,000 in goods was produced. The problem before them was, can the values of the manufactures be raised by increasing the skill of the workingmen? Many of our mechanics leave us for other countries, and it is vastly important that by increasing the amount of our manufactures and by raising the value of our goods and by increasing the skill of the workmen that we keep these men within our borders.

The Minister closed by saying that he would take the chair and endeavor to direct the discussion so as to best get at the information he desired to obtain, and at the same time to benefit all present. There were three questions to be considered :—

(1) Is there a scarcity of skilled labor?
(2) Where does our skilled labor come from? Do we produce or import it?
(3) What is the best way to procure for us the right kind of skilled labor?

He had received a large number of communications from persons who were delighted at the object of the meeting, but who were, unfortunately, prevented from being present; among whom were the Mayor, Messrs. Bertram & Son, Mr. Herbert Mason and a formidable bundle of others that he refrained from reading.

The Minister then announced the course which he proposed to take in utilizing the meeting to the best advantage for himself and those interested. He would ask manufacturers and mechanics in the different grades of manufactures to give their views, and to begin with, he would ask the representatives of the engineering department to address the meeting.

Mr. William Powis, public accountant, desired to make a suggestion. He said that the Governments of the Provinces should establish a system of registration, in which would be recorded the demand and scarcity of skilled labor and the number employed.

Mr. Ross—That has been done recently in this Province by the Bureau of Statistics.

Engineering Department.

Mr. Polson, president of the Polson Iron Works, Toronto, was then called upon to state the requirements of the engineering department of iron manufactures. He read a memorandum which was drawn up at a meeting called by the marine and stationary engineers of Canada touching the establishment of a School of Practical Science as applied to industrial pursuits It brought out the following points :—(1) That technical education should begin in the public schools. (2) The establishment of night schools for teaching industrial handicraft, for the encouragement of which there should be founded scholarships. (3) The equipment of the schools with such machinery as would give the pupils a thorough training in the use of tools, the strength and durability of material, and the various uses to which it can be applied.

Mr. Ross—Do you import any skilled labor yourself, Mr. Polson?

"Yes; from England and Scotland."

"For what purpose?"

"For steel shipbuilding."

"Where have the skilled laborers you now employ been trained?"

"In Canada, the States and Europe."

"Were any of them trained in the School of Practical Science?"

"No."

"How many skilled laborers have you now?"

"About 400."

"Have you suffered from the want of skilled labor in your business?'

"We suffer every day. Our industries could be made more profitable to ourselves, and, consequently, to our employés, if the latter had received a thorough theoretical and practical training."

"Have you many skilled laborers in your employ?"

"About 80 per cent."

"What became of the more highly-skilled mechanics in your establishment?"

"They left for better positions."

Mr. Ross at this stage announced that Sir Daniel Wilson and Col. Gzowski, who were present, had to leave in a short time, and knowing that the meeting would like to have their views, he took the liberty of asking them to say a few words.

Col. Gzowski thanked the Minister of Education for bringing together so important a gathering. Practical skilled labor is of high moment, and whether the population of Canada can supply all the skilled labor necessary is a matter of deep consideration. In France and Germany the workshops are indispensable. The success of the works which he (Col. Gzowski) constructed was due to the fact that he always took the skilled advice of practical men. Instances were given showing that men in the humblest positions had rendered signal service in solving mechanical problems. The only way to make men practical is by the School of Practical Science proposed to be established. (Applause.)

Sir Daniel Wilson prefaced his remarks by saying that his brother presided over the first technical school established in Britain. That school was in Edinburgh. The School of Science in connection with University College was originally founded on an absurd basis. The building is not adequate and other appliances are inadequate, because practical men had not been consulted in the organisation of the school. He paid a high tribute to the teaching staff, but urged that they were hampered in their work by lack of accommodation. The speaker hoped public opinion would sustain the Minister of Education in placing the school on a proper basis, believing that the province would reap rich results.

The discussion of the engineering department of manufactures was then resumed.

Mr. Leonard, manufacturer of engines and boilers, London, Ont., gave some eminently practical information. He heartily agreed with the Minister of Education in

establishing the School of Practical Science on the basis proposed. He employed 75 skilled laborers, 50 of whom would do better work if they had received better training. They were good enough mechanics, but if they had had the advantages of technical education they would be more useful to their employers.

Mr. Macorquodale—Is the public suffering from the inferior articles produced by what is called unskilled labor ?

Mr. Leonard—We take care that inferior articles are not produced by efficient and attentive supervision. We suffer ourselves from the lack of skilled laborers, and our employés are certainly injured in their prospects by want of proper training. It is in their interests that I am here to-day. (Cheers.) Employers have to pay mechanics according to their skill. Seventy-five per cent. of employés are Canadians, the balance are from other countries. They are all self-taught.

Mr. Davidson—I should like to ask, Mr. Leonard, if it is not a fact that Canadian manufacturers prefer United States designs to those of their own country.

"Yes ; because the Canadian and American practice is similar."

Mr. Leonard, in answer to a question, said that it is in theoretical mechanics that skilled training is necessary. If the school were to be organized he would send three students in three weeks. (Applause.)

Mr. Inglis, of Inglis & Hunter, then addressed the meeting. He said that he employed 90 men, not one of whom had taken a course at the School of Practical Science. He employed one draughtsman who had received a technical education. His men were deficient in theoretical training, but in practical mechanics they could not be beat. There are not three of the number employed who could design a steam engine. The foreman gets $3 per day. He thought his workingmen would attend night schools, as many of them express a regret that there were not such institutions where they might learn more theoretical and practical skill.

Mr. A. H. Campbell—What proportion is the skilled labor in your works to the unskilled ?

Mr. Inglis—We have only about 20 unskilled laborers in our place.

Iron and Wood Workers.

Messrs. E. Gurney, W. H. Withrow, and others have an innings.

Mr. E. Gurney, of the Gurney manufacturing establishment, was called on to speak in behalf of stove manufacturers. He said that he was always interested in the cause of practical and theoretical training of artisans. Never were manufacturers more indebted to a Minister than to Mr. Ross for calling the meeting. It would result in good. There was too much attention paid in the past to the learned professions. The School of Practical Science is going to assist the manufacturers in future. He would rather give his money for practical education than for any other purpose he knew of. The power of using tools is a necessary factor in technical education. Facility of head and hand are requisite for every skilled mechanic. In his establishment there are not four men who had received a technical education. All manufacturers lose money by the want of skilled labor. An enormous amount of money is lost because men do not know the chemistry of their work. How many men know, for example, the chemistry of iron ? Very few. It is time this should be changed. The loss of the manufacturer is the loss of the men. In reference to the School of Practical Science, Mr. Gurney said that it ought to be made a place of practical utility. It should be so organized that it should be managed by a board thoroughly representative of men of all classes. We can get as good patternmakers in Canada as in the United States, but their skill would be increased by a course of more or less training in technology.

Thomas Lloyd—Would not a thorough apprenticeship system be better than technical education, Mr. Gurney ?

Both together would still be better. (Laughter.)

Mr. Gurney proceeded then to illustrate the benefits accruing to the mechanics themselves from the highest skill possible in their work, arguing that they not only made more money but they also received the respect and esteem of their employers and fellow-employés.

W. H. Roden, of Toronto, had never known of a time yet when skilled labor was not to be had in Toronto, but admitted that there was a scarcity of educated labor.

W. H. Withrow was the first of the wood manufacturers to be called upon. He said that the apprentice system has been entirely given up in his department in Canada, and they were compelled to depend for their best men upon those who graduated from the workshops of the Old Country. His experience was that the best man is always the cheapest man.

In answer to the Minister, he said that he employed about one hundred men, none of whom had any technical training. He paid his best trained men the highest wages.

To Mr. Lloyd, he said that it would be a benefit to the journeyman carpenters were a thorough system of apprenticeship established, and also that it would benefit carpenters who are devoid of this training if the proposed school would provide classes in the evening which they could attend. He thought the younger and more ambitious would take advantage of this opportunity.

Mr. Thomas Moore opined that it was evident from the tone of the meeting that the imparting of technical education to mechanics and artisans was an absolute necessity. He advocated dotting the Province and the different districts of the city with "technical education" schools. From years' experience with carpenters, he was confident that they would take advantage of such schools gladly.

The Minister pointed out that they had 186 Mechanics' Institutes in operation throughout the Province last year, and they were attended by only 2,000 students.

Mr. Moore feared that many workingmen thought these institutes impracticable. A man in his trade must have geometry—it is virtually his right hand.

Hon. Mr. Ross—These institutes teach geometry.

Rev. Dr. Wild urged that these proposed schools should be for this distinct purpose alone. The failure of the Mechanics' Institutes was that so many different classes attended there.

Mr. Boustead, architect, favored the establishment of technical schools. He said, in answer to Hon. Mr. Ross, that it would be a great advantage to him to have a place in Toronto where the strength of wood, plaster and cement could be tested. Now they must go to the States to get these materials tested.

Mr. Smith, architect, confessed that they had no means of testing wood, brick or iron. In iron he depended upon formulas.

Mr. Gurney—Isn't it dangerous to depend upon formulas in iron?

Several architects—Yes, very dangerous.

Mr. Rogers, manufacturer of woodwork, found plenty of skilled men in Canada for his business. He was heartily in favor of giving as much information as possible to boys about to learn a trade. He had had a great deal of experience in training boys, and described quite vividly the details of his methods.

To the Minister, Mr. Rogers said that now he had to import no woodcarvers. The drawings for woodcarvings could be taught in a technical school or at a night school.

Thomas Lloyd proceeded to say that carpenters did not object to the School of Practical Science, but they objected to manual training in the Public schools.

Mr. Ross here interposed by saying that manual training was not before the meeting. He might call one to consider that matter.

Mr. Withrow advocated the having in connection with Mechanics' Institutes technical classes in the most practical sense of the subject.

Mr. A. F. Jury said that a feeling prevailed in Mechanics' Institutes that mechanics are not wanted there.

Mr. Ross—I never thought they were created for aristocrats. (Laughter.)

Woollen Manufacturers.

The movement calculated to greatly benefit this industry.

Mr. Wilby, woollen manufacturer, Weston, claimed that a great deal of importance ought to be given to this branch of manufactures. Woollens were largely manufactured in Canada, and he believed a School of Practical Science would do much towards perfecting to a larger extent, the finishing, dyeing and designing branches of the trade. He employed from 175 to 200 men, one-half of whom, as a rule, hailed from European countries. Of the whole number only one had received a technical education. The speaker closed by an earnest appeal for the establishment of the School of Science on the lines proposed by the Minister of Education, and by endorsing the views expressed by previous speakers to the effect that unskilled labor is a daily loss to every employer.

Applied Chemistry.

Mr. R. W. Elliott champions this subject in an able speech.

Mr. R. W. Elliott took the platform to champion the cause of applied chemistry as a branch of national education. He assured the Minister of Education that he would have the sympathy of manufacturers and workers in the course he proposed taking. Every loyal Canadian would assist in lending all aid possible towards making technical education a success, because if properly understood, untold wealth and commercial enterprise would result therefrom. He warned the meeting against looking for immediate results from the school, but good would eventually flow from its teaching. He dealt in dyes, most of which were imported. Some of them must be imported, but many of them could be manufactured in Canada if skilled labor were available. The speaker then went on to relate the course pursued in England and on the Continent with respect to technical education. Boys graduated from the technical schools to the workshops, bringing with them there the skill of hand and the knowledge of the component parts of the raw material. It was this feature of education that enabled the artisans of the Old Country to turn out articles of a highly finished and artistic character. He closed a very practical address by dwelling on the good to be achieved from a school which should have on its curriculum applied chemistry, and again assuring Mr. Ross that his scheme would be universally endorsed.

Various Speakers.

Prof. Shuttleworth, Mr. Curry, Vicar-Gen. Rooney, and Principal Dickson.

Prof. Shuttleworth was very glad of the inauguration of this movement, inasmuch as he owed no small share of his training to such a technical school. He quoted Prof. Roscoe in support of technical scientific training, and stated that in his line they imported many articles that might be produced here. For instance the gas works have allowed large quantities of ammonia to run to waste, defiling the bay for years, and they were just about preparing to manufacture it in a soluble form, which would add $70,000 odd annually to the wealth of the country. He strongly recommended the addition of night classes to the schools.

Mr. Curry (Darling & Curry), secretary of the Architects' Guild, said that there were several boys in the city, to his knowledge, who thought of going to the States for a technical training. His great difficulty was to get his young men to consider the strength of building material and the strongest methods of putting them together. This was certainly a great loss to the profession and to the public. He thought it would be of immense value to the profession to have an historical training in the various styles of architecture, as well as some culture in acoustics, ventilation, etc. He was of opinion that, were such a school established, the members of the Architects' Guild would compel their students to attend. This statement was applauded by the other architects present.

Vicar-General Rooney appeared for the Separate School Board, and earnestly favored the proposal. Such a school would provide practical training for their young men and make them better citizens. In the Separate Schools they had something of drawing, but thought that it should be greatly increased.

Principal Dickson, of Upper Canada College, thought that little more than drawing and amateur modelling could be taught in the Public schools, but in residential schools, such as the one at whose head he was, much more could be done. The lads there could be taught a little carpentering, or photography, or some similar occupation, when they, perhaps, could not go on the play-ground.

Saw Mills.

Mr. A. H. Campbell names one more industry to be benefited.

Mr. A. H. Campbell, just before the meeting came to a close, instanced the case of saw mills as industrial concerns demanding skill, care and dexterity. He warmly endorsed the proposed School of Science, believing that the fullest and most useful education should be afforded every man in the nation. He would not approve of admitting every applicant to the school, because there are boys so constituted that such a training as given in technical schools would be of no use to them.

Dr. Wild then proposed a vote of thanks to the Minister of Education for bringing such an interesting meeting together, which was seconded by Mr. Gurney in terms that left no doubt of his warm sympathy with the scheme proposed.

Before the vote was put, Mr. A. F. Jury assured the meeting that trades organizations were not opposed to technical education as explained by Mr. Ross and the various speakers during the afternoon. He proposed that the school to be reorganized should also teach the distribution of wealth and kindred economic subjects.

A Geologist and Mineralogist.

361 Spadina Avenue, 19th Dec., 1888.

Sir,—May I ask you to give me space to put in a plea on behalf of a class of industries which did not come under discussion at the meeting held under the presidency of the Minister of Education this afternoon, viz., those which have to do with the development of the mineral resources of the Province?

My plea is that instruction shall be given in mineralogy and structural geology to men who propose to employ such knowledge in actual field work, as miners or prospectors. A knowledge of mineralogy is necessary to enable them to distinguish mineral substances and know their properties, whilst an acquaintance with structural geology will enable them to prosecute the search systematically, recognizing the relation of the ore-bearing rock or the rock being quarried for commercial purposes, to other rocks with which it may be associated. Elementary chemistry is, of course, involved in mineralogy, whilst some acquaintance with palæontology will be necessitated by a study of structural geology.

I think it is little known what a large and increasing army of men take the field annually for the purpose of discovering valuable ore deposits or other mineral substances of use in the arts. These men should be qualified for their work by such instruction, and I need hardly point out that they should have free access to a complete collection of specimens of all the mineral substances known to occur within the Province.

As an incentive to diligence I would recommend that certificates of attendance and proficiency should be given periodically, which would aid the recipients in obtaining employment.

James T. B. Ives, F.G.S.